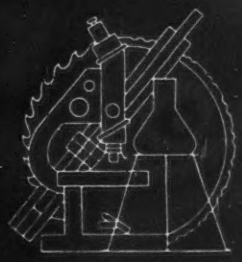
Featured this issue: WOOD PRESERVATION

Forest Products Journal



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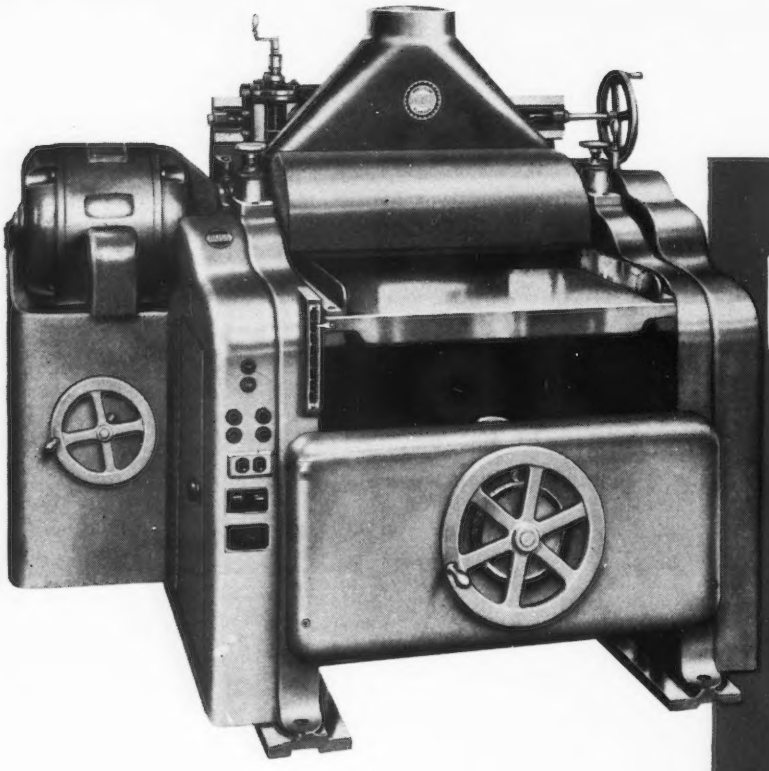

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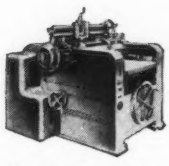

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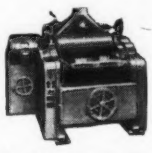

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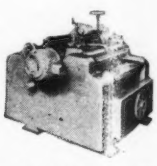

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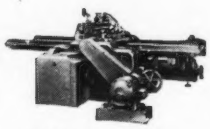

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THE FOREST PRODUCTS JOURNAL is published monthly by the Forest Products Research Society, 417 North Walnut Street, Madison 5, Wisconsin. Second-class postage paid at Madison, Wisconsin.

Annual subscription rate, $15.00; single copies $1.00, except October Yearbook Number, $4.00. Annual subscription rate is $11.25 with voting, associate, and supporting memberships in the Society. Remittances should be made payable to the Forest Products Research Society.

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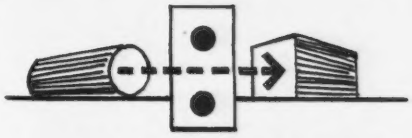

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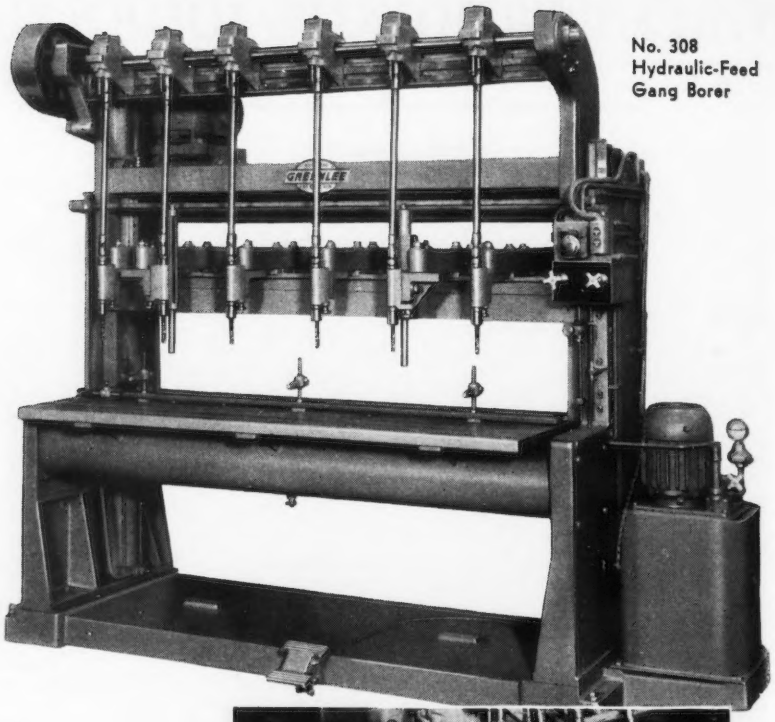

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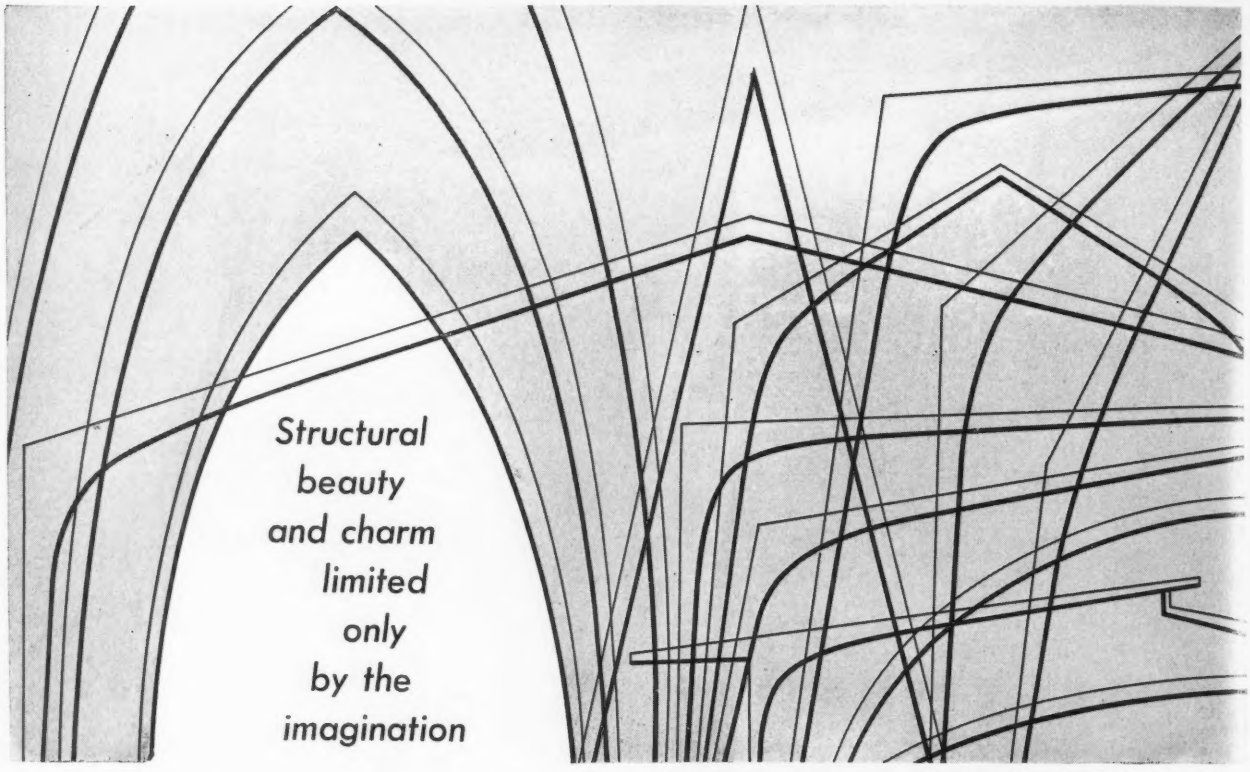

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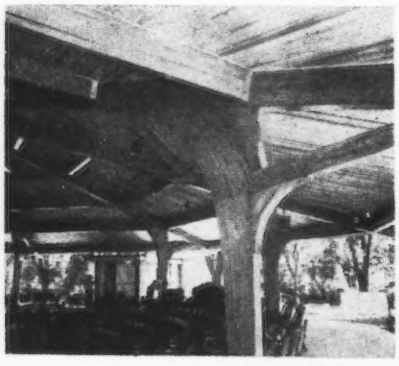

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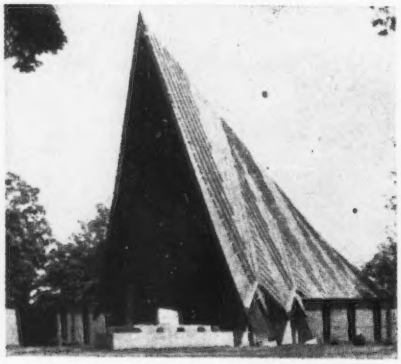
Carousel Theater, University of Tennessee—Penacolite adhesives bond these exposed timbers. Building octagon shaped. Arches—"V" type. Span—60'.



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Church in Conover, N.C.- Bonding adhesives—Penacolite. Arch span varies from 37'3" to 97'10". Roof pitch varies per foot from 34-27/32" at one end to 4-5/8" at the other.

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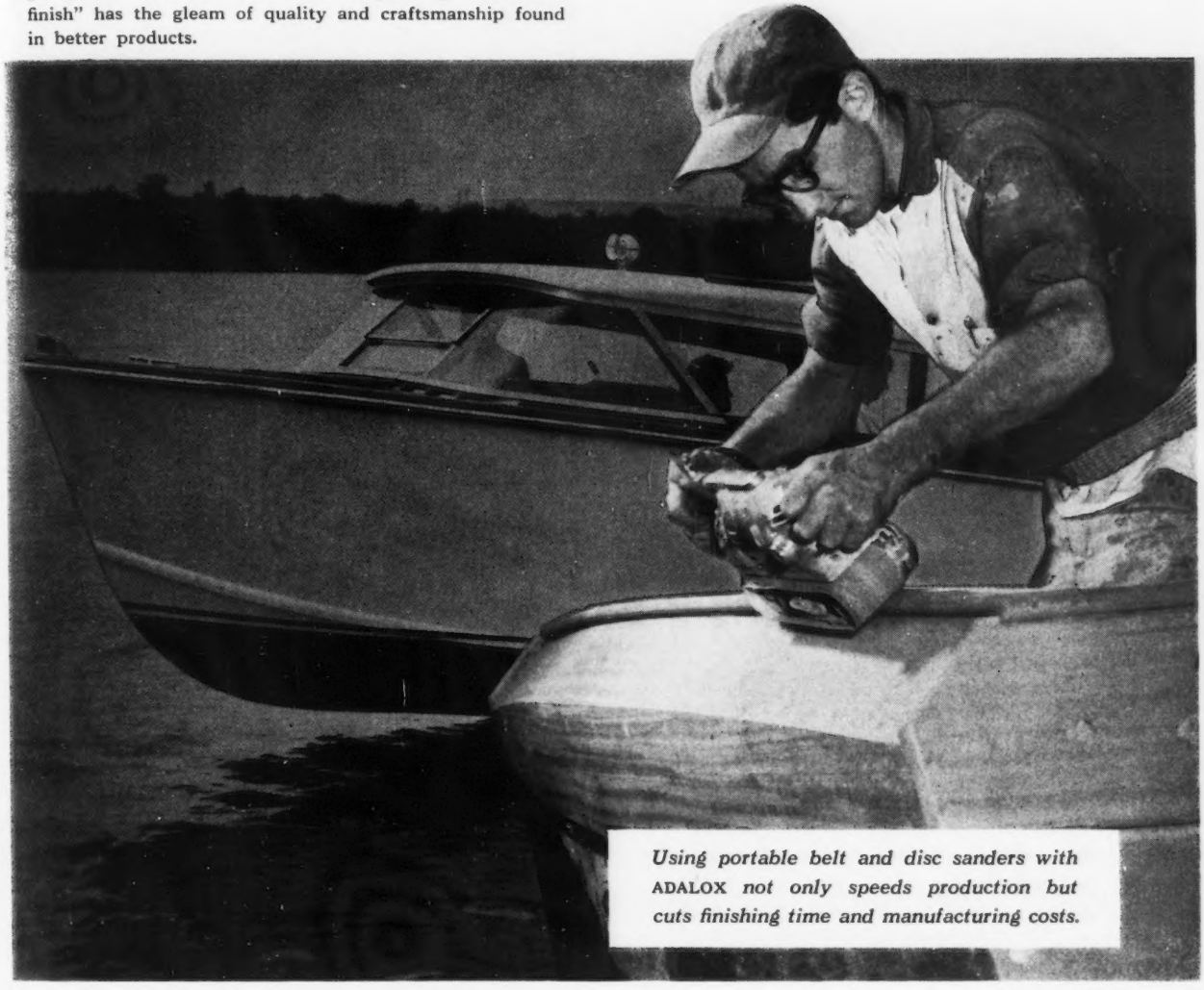

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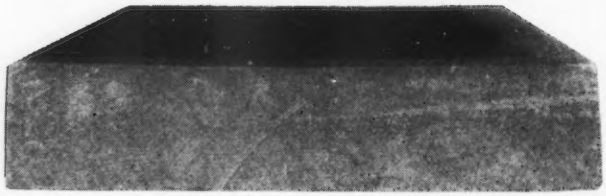

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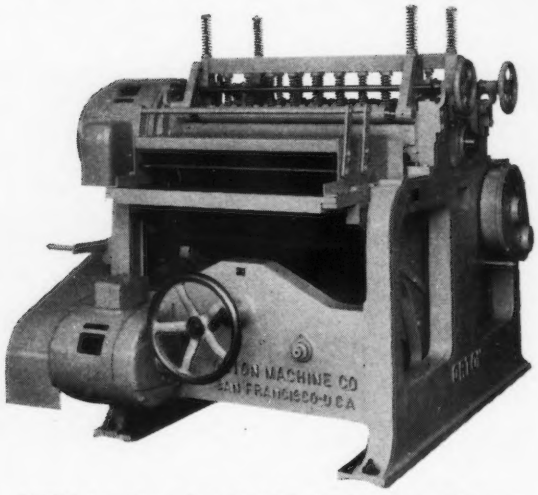

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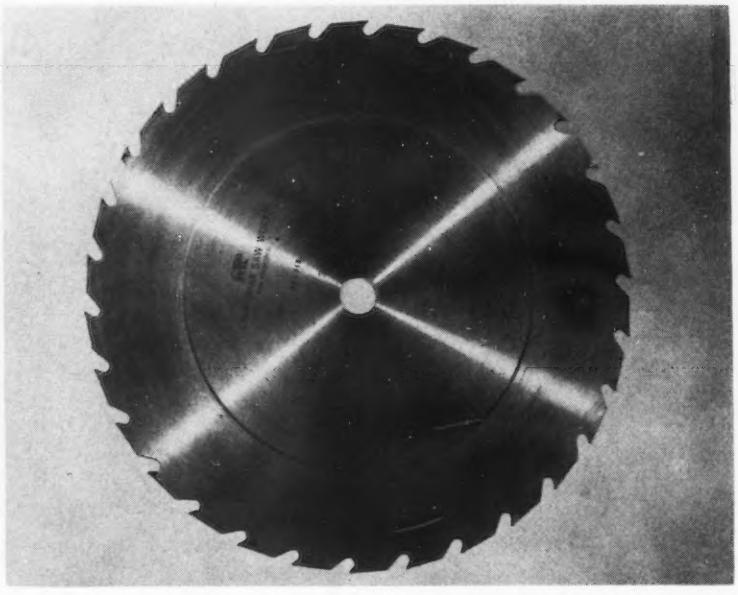

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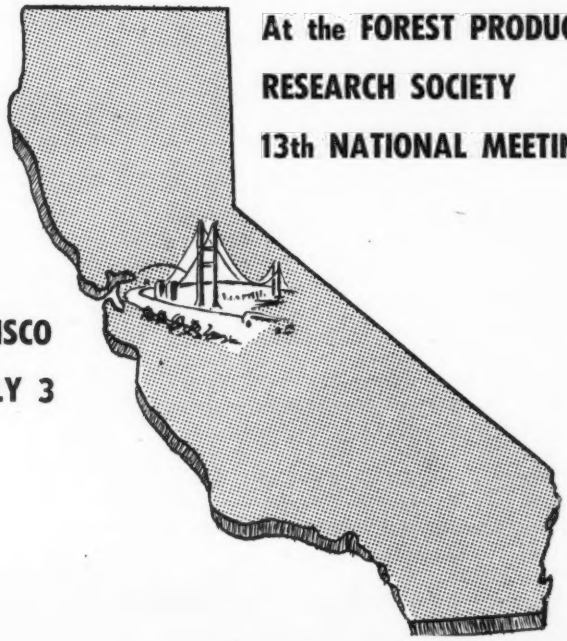

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VOL. IX, NO. 5
MAY, 1959

Treating Ponderosa Pine Millwork BY THE VACUUM PROCESS[1]

H. J. GILL, JR.
Product Development Manager,
CARADCO, Inc., Dubuque, Iowa

The vacuum process of applying water-repellent preservative provides: more output with less labor; a drier product; better penta distribution; less over-treatment of "sinker stock". The treated millwork meets NWMA penetration and retention requirements.

Fig. 1.—Millwork rolls into the upper half of the cylinder at the start of the vacuum process.

SIX YEARS OF EXPERIENCE with the vacuum system for the water-repellent preservative treatment of ponderosa pine millwork has resulted in the development of some interesting statistics and data. Not only has the process itself proven to be successful in the reduction of labor, a cleaner operation, less time-consuming between treating and glazing of sash, a superior distribution of preservative in the treated areas, and less likely to over-treat "sinker-stock", but also the technical procedures used to standardize the process produced information not previously reported.

Since it was necessary to certify that the vacuum system produced results equivalent to a three-minute atmospheric dip, a test program was established to accomplish this requirement. It was soon found that there was no recorded data that established the exact results of the three-minute dip. Through the use of an extensive series of samples and the evaluation of the total series and portions thereof, the results of the three-minute dip were determined, and the proposed vacuum cycle was verified as being equivalent.

The large number of samples used allowed a determination of the frequency of "sinker-stock" occurrence, and the effect on it of the two procedures. Since the samples were identical in size and shape, and accurate weighings were required, data on specific gravity were very conveniently developed. These same figures also showed there is no correlation between specific gravity and absorption, as had once been indicated.

History of the Vacuum Treating Equipment

After three years of extensive laboratory, engineering, and construction labor, a vacuum system was put into operation in the early part of 1952. This equipment consists of a treating vessel (Fig. 2) with two parts: a lower, fixed portion containing the water-repellent preservative solution, and a movable upper half. When the upper half is raised (Fig. 3), millwork, on factory trucks, may be loaded onto a grill-work floor within the vessel (Fig. 1). The upper portion of the vessel is then closed (Fig. 4), with its bottom rim seated in a gasket so as to develop an air-tight seal.

In conjunction with the vessel are the timer, which electrically actuates air-controlled valves to sequence the entire operation, the vacuum accumulator, and the steam injector for developing the vacuum. The upper half of the vessel and the grill-work platform, or elevator, are operated by means of air cylinders.

After the vessel is loaded and closed, an initial vacuum is applied (Fig. 5). Simultaneously, the elevator lowers the millwork into the solution. Air-controlled hold-downs prevent flotation. When a pre-determined degree of vacuum is reached, the vacuum is broken, which results in the solution being forced into the millwork (Fig. 6). The millwork is then raised to its original position (Fig. 7) and a second or drying vacuum is applied to remove excess solution.

At the end of this cycle, which coincidentally requires three minutes, the vessel opens and the millwork is removed. The equipment is then ready for another load.

[1] Presented at the Fall Meeting of the Mid-West Section, FPRS, Nov. 3–4, 1958, St. Louis, Mo.

The Author: James Gill holds a BS degree in chemistry from the University of Dubuque. He is chairman of the Preservative Standards Advisory Committee of NWMA.

Fig. 2.—Fixed lower portion of the vessel, which contains the water-repellent preservation solution.

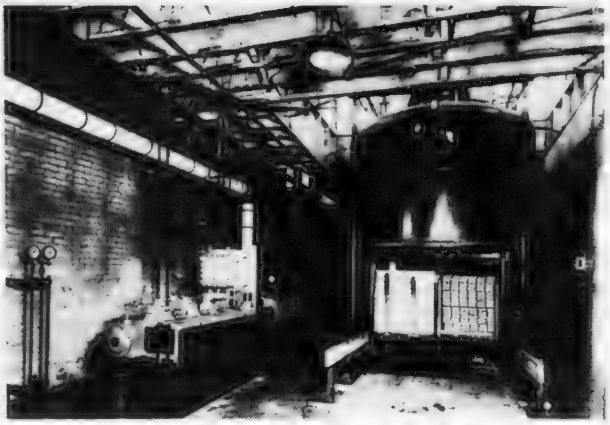


Fig. 3.—Movable upper half of the vessel in the open position with a load of millwork to be treated.

This procedure has now been followed daily for six and one-half years without failure. The work area is much cleaner and completely safe. Since all operations are controlled by a sealed timer, perfection duplication is always achieved. Only one operator is required as compared with two for the atmospheric dip, and twice the volume of millwork is treated in a comparable period of time.

Cycle Evaluation Procedure

The first evaluation program established was a laboratory model of the proposed equipment. This was utilized to prove the value of the vacuum idea. This equipment quickly demonstrated the feasibility of the principles involved, and an order was placed for the installation. During the construction period, several mechanical changes were made, but the basic principles remained unchanged.

An operating cycle for the equipment was developed from figures computed from the scale-model laboratory operation. To verify the cycle, an extensive comparative program was established with factory truck loads of millwork. Twenty-six loads were weighed before and after treatment in the 3-minute atmospheric dip. Thirty-eight loads were processed in the same way by the vacuum equipment. An analysis of these weights showed that the vacuum system resulted in 13.8 per cent better retention than the 3-minute dip.

Because a multitude of variations existed in this relatively informal basis of comparison, it was decided that a matched set of samples should be prepared so that the penta retention could be determined quantitatively.

Eleven pieces of ponderosa pine were ripped in half, then cross-cut in half to produce 44 samples. Half of these (two pieces from each original sample) were treated by vacuum, and the balance by the 3-minute dip. This test resulted in a figure of 19 per cent more treatment by the vacuum process.

Increment borings from these samples were quantitatively analyzed by the suppliers of the equipment by means of the lime-ignition method. These tests resulted in the data shown in Table I.

The analysis of the findings of this third evaluation program definitely established the relationship of the two procedures, and not only verified the over-treatment, but also demonstrated the more even dispersion of the retained penta.

On the basis of these evaluations, the vacuum equipment was put into production. The question of over-treatment and the large number of variables in test samples still troubled the staff. Also, more specific information on which to base claims for certification was needed. For several months, the staff searched for some material that could be used as a reference or control to permit anyone, under any conditions, to establish a "reproducible results" evaluation program. Finally, it was decided that an extremely large number of carefully selected samples of ponderosa pine would be the best procedure. Five hundred pieces of 5/4 cut stock 4½ by 48 inches, were carefully selected to eliminate any heartwood, pitchy stock, and defects. These were then quartered and surfaced so as to result in 2,000 samples, in four matched sets of 500 each. All samples had freshly machined surfaces.

Two sets were used for the test program, with the other two being retained for future programs. Each set was loaded on a factory truck with strips between layers and spaces between pieces to provide adequate and comparable ventilation. Each piece was weighed individually to the nearest 0.1 gram. Load I was processed through the 3-minute dip and load II through the vacuum process. Each piece was again weighed 24 hours after it was treated, and then seven days and 30 days after it was treated. The resultant figures were then analyzed.

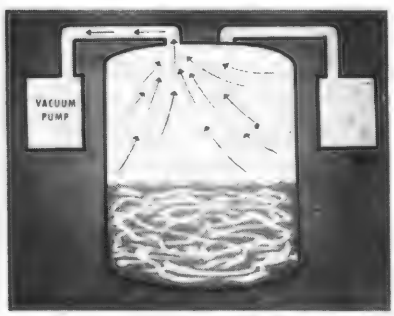


Fig. 5.—Vacuum is applied as millwork is lowered into the solution.

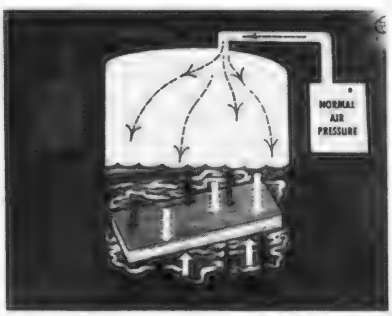


Fig. 6.—Preservative is forced into the millwork when the vacuum is broken.

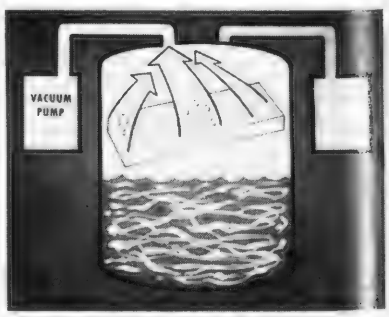


Fig. 7.—Excess solution is removed by a drying vacuum.

Last Chance to Pre-Register for FPRS' 13th NATIONAL MEETING

Use Registration Form, p. 10-A

FPRS News-Digest

"Research for Profit" at San Francisco, June 28 through July 3

SOME 600–700 PERSONS, principally from the United States and Canada, are expected to attend the FPRS 13th National Meeting at the St. Francis Hotel, San Francisco, June 28–July 3, according to General Chairman, Raymond H. Berry, and Technical Program Chairman, E. S. Harrar.

The technical program comprising 20 sessions, covering the full range of forest products technology from logging and lumber through to wood finishing and chemical utilization, will be the largest in the Society's history. Over 100 authors, panelists and presiding chairmen are contributing their efforts to the success of the meeting.

Registration Begin Sunday

Registration will begin 1:30 p.m., Sunday, June 28, and continue throughout the week. Fees of $12.00 for members and $14.00 for nonmembers will include admission to all technical sessions, Division and committee meetings. Women's registration fee is $6.00.

Institute of Wood Engineers Meet

FPRS activities on Sunday will include afternoon meetings of the National Executive Board, the Employment Committee, the Membership Committee, and the Publications Committee.

Technical and business meetings of the American Institute of Wood Engineering will be held on Sunday afternoon, June 28, at the St. Francis Hotel in San Francisco. The technical meeting will feature a paper on collapse of wood, to be presented by Dr. Eric Ellwood of the University of California, Forest Products Laboratory. The business session will be devoted to a review of AIWE progress and a look at what lies ahead. Three special committees have been working on important phases of the organization of AIWE. They are the committee on membership requirements, headed by Dr. H. O. Fleischer; the constitution committee, headed by Dr. F. F. Wangaard; and the name committee, headed by Dr. F. E. Dickinson. The activities of those committees and other matters of importance to the group will be discussed a the business session.

Mrs. Claire Canty and Lt. Gen. James M. Gavin, (USA Ret.), look over samples of wood products at the Arthur D. Little, Inc. laboratories. Mrs. Canty, a member of FPRS, has been doing research in chemical utilization of wood.

Welcoming Reception, Sunday Evening

Early arrivals will be guests of the Northern California Section at an informal and traditionally Californian "Wine Tasting" party starting at 7 p.m. in the Italian Room, Hotel St. Francis.

Week-Long "Suppliers' Exhibit"

Materials and services available to the wood industry will be displayed by more than 25 firms at the 38-booth Suppliers Exhibit to be held in conjunction with the meeting. The exhibit, open daily throughout the meeting, will be located in the Colonial Room and Corridor immediately adjoining the meeting rooms.

Annual Business Meeting

Members are urged to participate actively in the 13th Annual Business Meeting, 11:30 a.m., Monday in the Italian Room. Reports of the Executive Secretary, Budget & Finance, Membership, Publications and other committees will be presented. Results of the election will be announced.

Gen. Gavin Address, Officer Installation Highlight "Official Luncheon"

More than 400 registrants and their ladies will hear the address of Lt. General James M. Gavin, USA (Ret.), executive v.p. and director of Arthur D. Little, Inc., research institution, at the Official Luncheon on Tuesday, June 30.

Gen. Gavin, best known until his retirement in March, 1958, as Chief of Plans and Operations, Plans and Research, and Research and Development of the Dept. of Army, is currently concentrating in the fields of management research and administration; as well as heading-up further development of A. D. Little regional offices.

Publishers' Awards

A feature of the Official Luncheon will be the 10th annual presentation of the "Wood Award" for the outstanding and runner-up papers entered by graduate students in nine U. S. and Canadian universities. It will be presented by J. F. Koellisch, Editor and Manager of Wood and Wood Products magazine.

On Thursday, July 2, the 6th annual "Awards of Merit" will be presented by Robert Bolinder of Hitchcock's Wood Working, for organizations who have made significant contributions to the promotion or utilization of wood during 1958. Some 42 nomiantions have been made.

Registrants Urged to Attend Division Meetings

The 14 subject-matter Divisions are scheduled to hold open meetings, Wednesday, July 1. There will be no technical session held at this time. Registrants, whether members or nonmembers, are invited to attend and participate in the discussions at these meetings. The Divisions will be planning their technical programs for the 1960 Montreal National Meeting. They will plan their "Annual Review of Significant Developments" for the year 1959 to be published in the February 1960, FORST PRODUCTS JOURNAL. They will discuss participation in Section technical programs; and generally discuss industrial and technical developments in their fields.

(See Timetable, page 11-A)

DIVISION BUSINESS MEETING AGENDA

Glues and Gluing. 3:30–5:00 p.m., July 1

1. Election of a regular Committee Secretary (Regular election in 1960).

2. Consideration of a plan for Committee Reorganization. It is proposed that the Committee be reorganized with representatives appointed from each Section, with the approval of the Section Chairmen, in place of the present system of subject matter groups. Each Section representative will be a member of the Advisory Committee of the Division, which will also include the Chairman, Vice-Chairman, and Secretary, who shall be elected. The Advisory Committee shall be responsible for planning and directing the activities of the Division subject to the approval of the National office.
3. Brief reports on "What's New in Glues" around the country.
4. Plans for 1960 Technical Sessions.
5. Consideration of proposed Division By-Laws.
6. New projects for Division to undertake.

Wood Machining. 3:30–5:00 p.m., July 1

1. Outline of Division Organization with discussion.
2. Establishment of Steering Committee to support the over-all activities of the Division.
3. Appointment of 1960 Annual Program Committee and discussion of suggestions for topics and papers.
4. Explanation of need for a 1959–60 Annual Industry Report Committee, discussion, appointment of a chairman.
5. Reports of Saw & Knife Standardized Nomenclature Committee and goals for the year ahead.
6. Report of the Wood Machining Literature Survey Committee.
7. Appointment of a Nominating Committee for 1959–60.

Merchandising. 2:00–3:30 p.m., July 1

I. Call to order—Chairman—Wm. B. Lloyd
II. Roll Call
III. Minutes of Previous Meeting—Kenneth R. Peterson, Secretary
IV. Reports of Division Officers
V. Committee Reports
VI. New Business:
   1. Strengthening of Division organization
   2. Division–Section–Society relationship
   3. Duties of Division Officers
   4. Election of officers
   5. 1960 National Meeting Merchandising Technical Session

Packaging. 3:30–5:00 p.m., July 1

1. Discussion of Packaging Division status in the FPRS organization.
2. Definition of Division objectives and coverage within the field of packaging.
3. Election of Division chairman and co-chairman.
4. Appointment of Division committees for specific tasks.

Wood Preservation. 2:00–3:30 p.m., July 1

1. Discussion of plans for 1960 meeting; whether technical session or not.
2. Election of officers.

San Francisco Hotels

FPRS convention attendees may make reservations at the following San Francisco hotels. "S" means single rate, "D" means double, and "T" means twin. Numbers in parentheses indicate blocks from the St. Francis Hotel, FPRS convention headquarters.

Chancellor (1), 433 Powell St.; D $8.50, T $9.50.
Clift (2), Geary & Taylor Sts.; S $13–$21, T $16–$23.
Drake–Wiltshire (1), 540 Stockton St.; S $10, D $12, T $15.
Fielding (1), 386 Geary St.; D $1[illegible].
Franciscan (1), 350 Geary St.; [illegible] $7, D $9, T $12.
Golden State (2), 114 Powell S[illegible]; D $6.50–$7, T $8–$8.50.
Manx (1), 225 Powell St.; S $[illegible]–$9, D $9–$11, T $10–$12.
Plaza (1), Post St., T $12–$14.
St. Francis (Headquarters), Union Square; S $11–$22, D $13–20. T $16–$25.
Sir Francis Drake (1), Sutter & Powell Sts.; S $10–$15, D $1[illegible]–$17, T $15–$20.
Stewart (1), 351 Geary St., D $[illegible]–$10, T $10–$18.
Stratford (1), 242 Powell St.; S $5, D $6–$7, T $7–$8.

PRE-REGISTRATION FORM

THIRTEENTH ANNUAL MEETING—FOREST PRODUCTS RESEARCH SOCIETY

San Francisco, California **June 28–July 3, 1959**

Return to: Forest Products Research Society, P.O. Box 262, Burney (Shasta County), California

(PLEASE PRINT OR TYPE)

Name _____
(Last Name) (First Name) (Middle Initial) (Mrs.)

Address _____

City, Zone, State _____

Company or Organization _____

REGISTRATION (Includes Paul Bunyan Cocktail Cruise on San Francisco Bay)

		Enter Amount Below
FPRS Member	$12.00	$_____
Non-Member	14.00	_____
Ladies	6.00	_____
Children (no charge) Name _____ Age_____		
Name _____ Age_____		
FPRS Official Luncheon, per ticket	4.50	_____
FPRS Banquet, per ticket	8.00	_____
Ladies' Fashion Show Luncheon, per ticket	2.75	_____
Ladies' Sightseeing Tour of City, per ticket	3.50	_____
	Total Registration Fees	$_____
Hotel and Type Room desired: _____	Total Hotel Deposit (see Hotel Registration above)	$_____
_____	Total Amount Enclosed	$_____

Make checks payable to: F.P.R.S. 1959 National Meeting Committee

FPRS Thirteenth National Meeting

Timetable of Events

June 28–July 3, 1959
San Francisco, Calif.

	SUPPLIERS' EXHIBITS	REGISTRATION EXEC. OFFICE PRESS ROOM LADIES LOUNGE	TECHNICAL SESSIONS	SPECIAL MEETINGS	DIVISION AND COMMITTEE MEETINGS	SOCIAL EVENTS	LADIES' PROGRAM	PLANT TOURS
Sunday								
A M	8-12	11-12						
P M	12-9	12-9		**12:30-5:00** Exec. Board Mtg. **1:30-5:00** Amer. Inst. of Wood Engineers	**3:30-5:00** Employment, Membership, Publications Com's. **3:00-6:00** Tellers' Comm.	**7:00-10:00** Welcoming Reception, No. Calif. Section, Hosts		
Monday								
A M	8:30-12	8:30-12	**8:45-11:15** I Wood Comp. Bd. (A) II Veneer & Plywood III Wood Machining	**11:30-12:30** FPRS Annual Business Meeting		**7:00-8:20** Authors' Breakfasts	**9:00-12:30** Kaffe Klatsch, St. Francis Hotel & Scenic Bus Tour	
P M	12-9	12-9	**2:00-4:30** IV Glues & Gluing (A) V Chem. Util. (A) VI Wood Presvn.	**4:30-5:30** No. Cal. Sec. Mtg. **7:30-9:00** Section Officers Mtg. Division Officers Mtg.		**5:30-6:30** Gen. Gavin Reception **7:00-9:00** Past Presidents' Dinner		
Tuesday								
A M	8:30-12	8:30-12	**9:00-11:30** VII Logging VIII Wood Drying (A) IX Wood Finishing (A)			**7:30-8:45** Authors' Breakfasts	**9:00-11:30** Breakfast, Continental & Tour of Fashionable Shops	
P M	12-5	12-5	**2:45-5:15** X Lumber Mfg. (A) XI Wood Finishing (B) XII Packaging	**12:00-2:30** Official Luncheon		**5:30-8:00** Paul Bunyan Bay Cruise and Reception		
Wednesday					**2:00-3:30 pm** L. Mfg. Presvn. V. & P. Q. C. Chem. Util. Mdsg. Indus.-Ed. **3:30-5:00 pm** Comp. Bd. Logging W. Drying W. Mchng. G. & G. Finishing Packaging			
A M	8:30-12	8:30-12	**9:00-11:30** XIII Lbr. Mfg. (B) & Wood Drying (B) XIV Glues & Gluing (B) XV Indus.-Ed.			**7:30-8:45** Authors Breakfasts		
P M	12-9	12-9		**12:00-1:30** Exec. Board—Section Officers' Luncheon		**6:00-9:00** Social Hour and Annual FPRS "Party"	**12:00-2:30** Luncheon and Fashion Show Canterbury Hotel	
Thursday								
A M	8:30-12	8:30-12	**9:00-11:30** XVI Merchandising XVII Chem. Util. (B) XVIII General	**8:00-11:30** Exec. Board Mtg. and Breakfast		**7:30-8:45** Authors' Breakfasts	**9:00-12:00** Decorator's Tour of Jackson Square	**10:00-7:00, Camino** Mich.-Calif. Lbr. Co. (Bus)
P M	12-9	12-9	**2:00-4:30** XIX Wood Comp. Bd. (B) XX Quality Control	**12:00-1:30** Exec. Board—Division Officers' Luncheon **2:00-5:00** Exec. Board Mtg.				**1:00-6:00, Antioch** Fibreboard Products (Bus) **1:30-5:00, Richmond** U. of C. F.P.L. (Bus)
Friday								
A M								**8:00-7:00, Ft. Bragg** Union Lbr. Co. (Bus) **8:30-6:30, Ukiah** Masonite (Bus) **9:00-6:00, Red Bluff** Diamond Gardner (Plane)
P M								

75 Companies Sponsor "Paul Bunyan" Bay Cruise

San Francisco. Seventy-five wood industry suppliers are sponsoring the traditional Paul Bunyan social hour at the Thirteenth Forest Products Research Society National Meeting. The event will be a cocktail cruise around scenic San Francisco Bay on Tuesday evning, June 30. The cruise will start from the Fisherman's Wharf area, returning two hours later. Sponsoring firms as of May 1 are:

American Cyanamid Co., New York, N. Y.
American Manufacturing Co., Tacoma, Wash.
American-Marietta Co., Seattle, Wash.
American Sheet Metal Works, Inc., Portland, Ore.
F. E. Barnett Co., Eureka, Calif.
The E. J. Bartells Co., San Francisco, Calif.
J. H. Baxter & Co., San Francisco, Calif.
Behr-Manning Corp., Troy, N. Y.
Black Bros. Co., Inc., Mendota, Ill.
Booth Kelly Lumber Co., Springfield, Ore.
The Borden Co., New York, N. Y.
C. K. L. Machinery Co., Oshkosh, Wis.
The Carborundum Co., Niagara Falls, N. Y.
Catalin Corp. of America, New York, N. Y.
Chain Belt Co., Berkeley, Calif.
Chapman Chemical Co., Memphis, Tenn.
Cheney Stud Co., Tacoma, Wash.
Cleworth Publishing Co., Cos Cob, Conn.
Coe Manufacturing Co., Painesville, Ohio
Collins Pine Co., Chester, Calif.
The Crossett Co., Crossett, Ark.
Crown Zellerbach Corp., San Francisco, Calif.
Decar Plastic Corp., Middleton, Wis
Diamond Gardner Corp., Chico, Calif.
Douglas Fir Plywood Assn., Tacoma, Wash.
The Dow Chemical Co., Midland, Mich.
Durez Plastics Division, Hooker Electrochemical Co., North Tonawanda, N. Y.
Fairhurst Lumber Co., San Rafael, Calif.
Fibreboard Paper Products, Inc., San Francisco, Calif.
Chas. A. Fowler Co., San Francisco, Calif.
Gamble Bros., Inc., Louisville, Ky.
Hitchcock Publishing Co., Wheaton, Ill.
R. Hoe & Co., Inc., New York, N. Y.
Ivory Pine Co., Dinuba, Calif.
Koppers Co., Inc., Chemical Division, Pittsburgh, Pa.
The Lilly Co., High Point, N. C.
C. M. Lovsted & Co., Inc., Seattle, Wash.
Mater Machine Works, Corvallis, Ore.
Mattison-Greenlee Service Corp., Rockford, Ill.
Mereen-Johnson Machine Co., Minneapolis, Minn.
Michigan-California Lumber Co., Camino, Calif.
Monsanto Chemical Co., St. Louis, Mo.
Moore Dry Kiln Co., No. Portland, Ore.
National Casein Co., Chicago, Ill.
National Lumber Manufacturers Assn., Washington, D. C.
Nelsonite Chemical Products, Inc., Grand Rapids, Mich.
Nicholson Manufacturing Co., Inc., Auburn, Wash.
Nickey Bros., Inc., Memphis, Tenn.
Orton Machine Co., San Francisco, Calif.
Pacific Manufacturing Co., Santa Clara, Calif.
Peter Cooper Corp., Gowanda, N. Y.
The Pacific Lumber Co., San Francisco, Calif.
Poinsett Lumber Manufacturing Co., Pickens, S. C.
Potlatch Forests, Inc., Lewiston, Idaho
Protection Products Manufacturing Co., Kalamazoo, Mich.
Rader Pneumatics, Inc., Portland, Ore.
Rees Blow Pipe Manufacturing Co., Berkeley, Calif.
Reichhold Chemicals, Seattle, Wash.
Roddiscraft, Inc., Arcata, Calif.
Scott Lumber Co., Burney, Calif.
Setzer Forest Products, Sacramento, Calif.
Simonds Saw & Steel Co., Fitchburg, Mass.
Ralph L. Smith Lumber Co., Anderson, Calif.
Southwest Lumber Mills, Phoenix, Ariz.
Standard Oil Co. of California, San Francisco, Calif.
Sumner Iron Works, Everett, Wash..
Tarter Webster & Johnson, Inc., San Francisco, Calif.
Union Oil Co. of California, Los Angeles, Calif.
U. S. Plywood Corp., New York, N. Y.
U. S. Plywood Corp., Redding, Calif.
Washington Iron Works, Seattle, Wash.
West Coast Lumbermen's Assn., Portland, Ore.
Weyerhaeuser Timber Co., Tacoma, Wash.
Wilco Machine Works, Memphis, Tenn.
Winton Lumber Co., Martell, Calif.

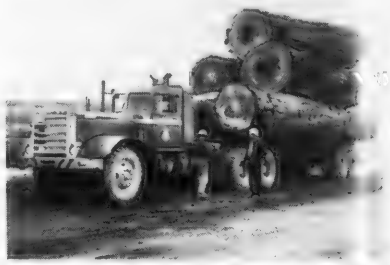
Two Days of California Plant Tours Scheduled for July 2, 3

An important feature of the 13th National Meeting, according to Tom Shelton, Diamond–Gardner Corp., chairman, will be visits to a variety of wood industry and lumber manufacturing operations, and to several research laboratories.

On Thursday, July 2, groups will visit Fibreboard Products Corporation, Antioch; Michigan–California Lumber Company, Camino; and the University of California Forest Products Laboratory, Richmond. All-day trips on Friday, July 3, include Union Lumber Company, Fort Bragg; Masonite Corporation, Ukiah; and the Diamond Gardner Corporation, Red Bluff.

Advance sign-up during the meeting will be required for all who wish to participate in one or more of the field trips. A charge will be assessed to cover the cost of transportation—by chartered bus on all trips except the one to Diamond Gardner Corporation at Red Bluff, which will be by chartered aircraft.

AERIAL VIEW of the California Forest Products Laboratory at Richmond, Cal.



A LOAD OF REDWOOD LOGS (5 to 6 feet in diameter) ready for transport to the Union Lumber Company mill at Fort Bragg. Load scales 17,000 bd. ft. (Humboldt scale).

HIGH SPEED IN-LINE FINISHING of blank stock is only one of many interesting features incorporated into the design of the new Diamond Gardner installation.

Twenty-Five Industry Suppliers to Exhibit Products and Services

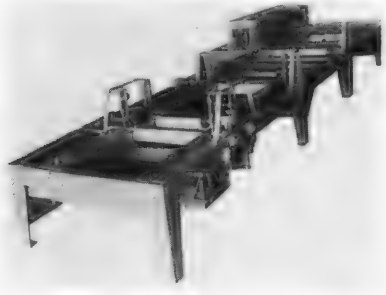
MORE THAN 25 machinery and raw material suppliers and lumber producers have reserved space in the booth and tabletop exhibit being held in conjunction with the 13th National Meeting.

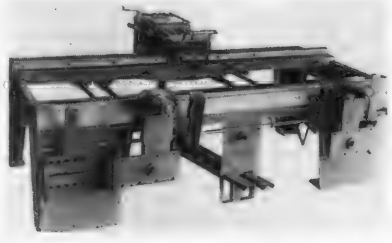
Products and services will be displayed in the Colonial Room and corridor immediately adjacent to the meeting rooms, in the St. Francis hotel.

Exhibitors to date include:

The Cardwell Machine Co., P. O. Box 1359, Richmond 11, Va. Representatives at Show: Henry S. Holland, III, Robert G. Redmayne. Items on display: Auto-Clip, Auto Panel Feeder, Veneer Tenderizer, Tangential Separator.

Irvington Machine Works, 1808 N. E. Seventh Ave., Portland 12, Ore. Representatives at Show: E. W. DeKoning, L. R. Hiatt, G. Leibel. Nature of exhibits: Model of Standard Dry Kiln Co. prefabricated kiln and a model explaining the use of IRVAC in automatic controls for lumber end-conditioning equipment.





Kvalheim Machinery Co., P. O. Box 77, Petaluma, Calif. Representatives at Show: Irwin S. Kvalheim and A. M. Kvalheim. Nature of exhibit: table-top exhibit with photographs and literature on most recent machines. Items on display: Model 440 BD for sizing doors, Model 990-R.

Masonite Corp., Chicago, Ill. Representative: Don Silk, Sales Promotion Mgr.

Stetson-Ross Machine Co., Seattle. Representative: C. W. Jones, Asst. Genl. Mgr.

Roddiscraft, Inc., Timblend Div., Arcata, Calif. Rep., R. K. Molloy, Manager.

Sel-Set Machinery Corp., Salem, Oregon.

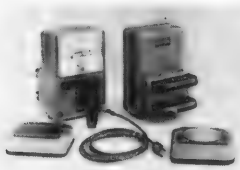
Sel-Set Machinery Corp., Salem, Ore.

Binks Mfg. Co., Chicago, Ill. Rep., Geo. Knetl, Asst. Dir. of Engineering.

Mann–Russell Electronics, 711 St. Helens Ave., Tacoma 1, Wash. Representative at Show: H. K. Haskell. Nature of exhibit: Table on which Bulletin Information will be given. Item on display: Finger End Joint Electronic Gluer.

Mater Machine Works, 520 South First Street, Corvallis, Ore. Nature of exhibit: Mater Packaged Automation Sawmills and Mater Automation Sawmill equipment—man-sized layouts of some typical Mater Packaged Mills for fir, pine, hardwood, and stud operation will be on display. Installation photos, literature on Mater equipment, automation examples, and reprints of articles on sawmill automation will be available.

Miller Hofft, Inc., P. O. Box 8718, Richmond 26, Va. Representative at Show: H. C. L. Miller. Nature of exhibit: Literature on processes, engineering, and equipment for particle board operations; particle board samples.

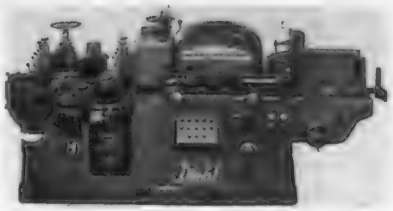


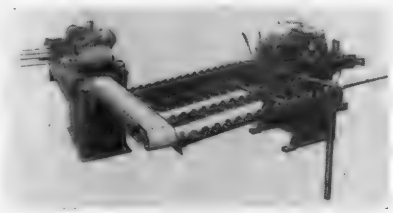
Moisture Register Co., 1510 West Chestnut St., Alhambra, Calif. Representatives at Show: Various sales engineers. Nature of exhibit: Complete line of electronic moisture meters for lumber. Items on display: Model 5 Line of radio-frequency type instruments, DC needle type instrument Model DC8, Granular Moisture Register Model G5, and others.

Timesavers Sanders, Minneapolis, Minn. Equipment: Top Speedbelt Sander, Model 18. Contact: R. G. MacCune.

Crown-Zellerbach Corp., San Francisco.

Nordson Corp., Amherst, Ohio. Equipment: Airless Spray Coating unit, literature and samples of finished wood products. Rep., Ed Hogstrom, Western Sales Mgr.





Orton Machine Co., 390 Fremont Street, San Francisco 5, Calif. Representative at Show: Collins Orton. Nature of exhibit: Pictures in table-top display. Items on display: woodworking machinery—single surfacers, gang rip saws.

Rowney Machinery Co., 600–16th Street, Oakland, Calif. Representative at Show: James C. Rowney. Nature of exhibit: Table-top display, photograph, literature, and movie "Finger Jointing and Assembling of Lumber". Items on display: Finger-jointing machinery.

Scott Lumber Co., Inc., Burney (Shasta County), Calif. Representatives at Show: Bernard A. Lewis, Charles C. Hughes. Nature of exhibit: Booth exhibit on FERTIMULCH, bark soil conditioner. Items on display: FERTIMULCH, chips for pulp products, and lumber.

Simonds Saw and Steel Co., 470 Main Street, Fitchburg, Mass. Representatives at Show: William Higgins, Max E. Schutte, Henry Keele. Nature of exhibit: General line of wood cutting products. Items on display: Circular saws (solid tooth, inserted tooth, and carbide tipped), band saws (both wide and narrow), gang saws, machine knives of all types, and saw sharpening files.

The S. H. Smith Co., 2232 N. Meridian Street, Indianapolis 7, Ind. Representative at Show: J. F. Burrell. Nature of exhibit: Display of wood working publications THE WOOD-WORKER and VENEERS AND PLYWOOD.

Smithway Machine Co., 4617 Airport Way, Seattle, Wash. Representatives at Show: O. W. (Jack) Smith, Glen Groth. Nature of exhibit: Smithway 50″ Top & bottom wide-belt sander, XL Moldmatcher 2″ x 6″ molder, XL Ripperpower feed, XL Kerf saver (band resaw).

Soderhamn Machine Manufacturing Co., 409 Pittock Building, Portland, Ore. Representatives at Show: Robert E. Peterson, B. Paul Kornberg. Nature of exhibit: Brochures on equipment that company manufactures and samples of particle board. Items on display: Samples and literature on Baehre Particle Board Equipment, Photographs and literature on Soderhamn Woodwaste Utilization Equipment.

Exciting Ladies' and Social Program Planned

Co-Ladies Committee chairmen, Marie Roth and Barbara Kuhn welcome you to San Francisco.

Monday's program includes a get-acquainted Kaffeeklatsch in the morning and a Scenic Bus Tour of the city that afternoon. The following day, a Continental Breakfast will precede a tour of some of the city's loveliest shops.

The Canterbury Hotel's Garden Court, a veritable oasis in the city, has been reserved for a Luncheon Style Show on Wednesday noon.

Attempts have been made to leave sizable "chunks" of time so that ladies can do some shopping or sight-seeing on their own. It may be a trip to Chinatown, a ride on a cable car, or a visit to the Mission Dolores. Golden Gate Park, with its planetarium and aquarium, and Fleishacker Zoo, including swimming pool and playground, will appeal to the children and adults alike. The breath-taking view from hilltops or skyrooms will not soon be forgotten.

Gray Line schedules bus tours for children. Reliable baby-sitters are available.

The Oasis Room in the St. Francis Hotel, reserved as Hospitality Headquarters for the ladies during the entire week, will be available for relaxing, meeting friends, or freshening up.

In addition to the events planned for them especially, wives will join their husands at the Sunday Wine Tasting at the St. Francis Hotel, the Paul Bunyan Cocktail Cruise on the bay, the Official Luncheon on Tuesday, and the Dinner Party Wedenesday evening.

Jane Mullally, leader of Melodairs Trio

Glen Hayward, Master of Ceremonies

The gala FPRS "Party", Wednesday evening, July 1, will combine an informal cocktail hour, and banquet followed by a star-studded show. The evening will close with dancing to the music of a nine-piece orchestra.

Some Tips from the Convention Bureau on Climate and Dress in San Francisco

In June and July when the city is enjoying its own private brand of air conditioning, the average temperature during the day is 65°; at night around 53°. Rain is most unlikely, but fog is a frequent evening visitor. San Francisco women favor lightweight wool suits and dresses and small hats, because of the breezes from the bay. Small furs, as well as hats and gloves, are frequently in evidence. It would be wise to include a dark silk basic dress in your wardrobe for the highly possible extremely warm day. A lightweight wrap is essential.

White shoes are rarely worn in San Francisco. However, if you are visiting friends down the peninsula or across the bridge in Marin County, you may choose to bring your light cottons and white shoes. A few miles from San Francisco makes a big difference; the temperature may climb into the 90's.

LADIES PROGRAM

Time	Event	Cost
Sunday, June 28		
1:00–8:00 pm	Registration—St. Francis Hotel	$6.00
5:30–8:30 pm	Wine Tasting	Guests of Northern California Section
Monday, June 29		
9:30	Kaffeeklatsch—Georgian Room—St. Francis Hotel	Complimentary ticket
1:15–5:00 pm	Conducted Scenic Bus Tour	$3.50
Tuesday, June 30		
9:15	Continental Breakfast and Tour of Shops	Complimentary ticket
Wednesday, July 1		
12:00	Luncheon and Fashion Show Canterbury Hotel, Garden Court	$2.75
Thursday, July 2		
10:00–12:00	Decorators' Tour of Jackson Square	Complimentary ticket

From The Cover:

Next FPRS President: Dean E. S. "Scotty" Harrar

Prof. E. S. "Scotty" Harrar, Dean of the Duke University School of Forestry, Durham, North Carolina, will receive the presidential gavel of office from out-going president W. Jeter Eason, Nickey Bros., Memphis, Tenn., at the FPRS 13th National Meeting in San Francisco this June.

Dean Harrar, or "Scotty" to his many associates who know and respect him, will receive the official symbol of office at the Official Luncheon, to be held Tuesday noon, June 30, in the California Room of the headquarters St. Francis Hotel.

A charter member of FPRS, Scotty has been a valuable man to the Society since its inception. He served as chairman pro-tem in the organization of the Carolina-Chesapeake Section in 1948, and was for several years Secretary-Treasurer and a Trustee of that Section.

In 1954, Scotty was elected to represent the Southeastern Region on the executive board of the Society, and thus extended his career of service to the wood industry on a national level in FPRS. His primary contribution during this term was the General Chairmanship of the 1956 National Meeting at Asheville, one of the largest and most successful in FPRS history. Over 800 persons attended the combined meeting and industry exhibit.

At the end of his three-year term as Regional Board Member, Scotty was elected to the Vice-Presidency in 1957, and was elected President-Elect in Madison, Wis., last June at the 12th National Meeting of FPRS. As Vice-President, Scotty worked hard to help establish the role of the Divisions in the over-all structure of the Society. Then, during the past year as President-Elect, the technical program of the 13th National Meeting was Scotty's charge. With almost 100 papers in a record 20 sessions, this will be the largest technical program in the 13 years of FPRS history.

Prof. Harrar began his collegiate training at Oberlin College, and earned his Bachelor of Science degree from the New York State College of Forestry at Syracuse. His MS and PhD degrees were also earned there in 1928 and 1936.

Harrar is first and foremost an educator. His first teaching position was with the University of Washington College of Forestry from 1928 to 1936, while he finished his PhD work. Harrar then came to Duke University in 1936, and was appointed Dean of the School of Forestry in March of 1957.

A specialist in the structural, physical and chemical properties of wood, Harrar is widely known for his writings. He has written extensively for forestry and forest products journals, and has co-authored several books, including the Textbook of Dendrology, Douglas-Fir Use Book, Guide to Southern Trees, Forest Dendrology, and Forest Products. The Encyclopedia Britannica contains over 70 new or revised articles on timber trees over his name.

FPRS 13th NATIONAL MEETING

Official Technical Program

Over 100 Authors, Program and Presiding Chairmen, and Panelists Combine Talents Toward Success of Largest Technical Meeting in FPRS' History, at San Francisco, June 28–July 3

ROBERTS

MARRA

HAMILTON

PARTICLE BOARD

Monday, June 29, 8:45–11:45 a.m.

Presiding Chairman: J. R. Roberts, Celotex Corp., Des Plaines, Ill.

Manufacturing Problems, by E. S. Johnson, N. C. State College, Durham, N. C.

Particle Board Research, G. G. Marra, Washington State Institute of Technology, Pullman, Wash.

Board Uses and Markets, J. F. Hamilton, Michigan College of Mining and Technology, Houghton, Mich.

LUTZ

KOEHLER

RIPLEY

VENEER & PLYWOOD

Monday, June 29, 8:45–11:45 a.m.

Presiding Chairman: John F. Lutz, U. S. Forest Products Laboratory, Madison, Wis.

Potential of Western Hardwoods for Veneer & Plywood. Peter H. Koehler, Timberline, Inc., Crescent City, Cal.

Motion Picture Studies of Veneer-Cutting at the Cellular Level, Lawrence Leney, U. of Missouri, Columbia, Mo.

Lathe Check Formation in Douglas Fir Veneer, E. H. Collins, Weyerhaeuser Timber Co., Longview, Wash.

New Performance Test for Interior Plywood & Application to Panels Containing White Pocket. Robert Ripley, Douglas Fir Plywood Assn., Tacoma, Wash.

Heating Douglas Fir Veneer Bolts—Does It Pay? G. H. Atherton & J. B. Grantham, Ore. Forest Products Research Center, Corvallis, Ore.

McMILLIN

OEHRLI

KVALHEIM

WOOD MACHINING

Monday, June 29, 8:45–11:45 a.m.

Presiding Chairman: C. B. Berolzheimer, California Cedar Products Co., Stockton, Cal.

Recorder: Jack Pfeiffer, Forest Products Research Center, Corvallis, Ore.

Research in Thin Circular Saw Blades, by C. P. Berolzheimer, and Cecil Best, Calif. Forest Products Lab., Richmond, Cal.

Circular Sawing Experiments on a Radial Arm Saw. C. W. McMillin & J. L. Lubkin, American Machine & Foundry Co., Stamford, Conn.

Cross-Cutting Research with Power Chain Saw Teeth. J. W. Oehrli, McCulloch Corp., Los Angeles, Cal.

Design Factors for Production Woodworking Machinery, by A. M. Kvalheim, Kvalheim Machine Co., Petaluma, Calif.

BLOMQUIST

HEMMING

BOOTH

GLUES & GLUING

Monday, June 29, 2:00–4:30 p.m.

Presiding Chairman: Richard F. Blomquist, U. S. Forest Products Lab., Madison, Wis.

Recorder: P. L. Northcott, Forest Products Labs of Canada, Vancouver, B. C.

The Technology of Elastomeric Adhesives—C. B. Heming, U. S. Plywood Corp., Brewster, N. Y. To be presented by August H. Rauch, U. S. Plywood Corp., Seattle.

Elastomeric Adhesives—Their Application in Forest Products Industry. C. C. Booth, C. P. Hancock & J. M. Hine, Borden Chemical Co., Bainbridge, N. Y.

New Approach to Lumber Laminating. George G. Marra, Washington State Institute of Tech., Pullman, Wash.

Finger Jointing at High Moisture Contents. R. A. Currier, Ore. Forest Products Research Center, Corvallis, Ore.

Status of Our Present Knowledge of Adhesion in Wood. J. E. Marion, Forest Products Laboratory, Richmond, and Arne Wissing, Stockholm, Sweden.

LOCKE

ANDERSON

MILLER

CHEMICAL UTILIZATION

Monday, June 29, 2:00–4.30 p.m.

Presiding Chairman: E. G. Locke, U. S. F.P.L., Madison, Wis.

Influence of Extractives on the Seasoning Stain of Redwood Lumber, A. B. Anderson, Eric Ellwood and Eugene Zavarin, Forest Products Laboratory, Richmond, Cal.

Distribution of Dihydroquercetin in Douglas-Fir and Western Larch Wood. J. A. F. Gardner and George M. Barton, Forest Products Laboratories of Canada, Vancouver, B. C.

Wood and Bark Products Used in Oil Well Drilling. R. W. Miller & Wm. G. Van Beckum, Pacific Lumber Co., San Francisco, Cal.

A Close Look at Charcoal Production Costs for Kiln Operation. Carl Arbogast and Charles E. Boldt, Lake States Forest Experiment Station, Marquette, Mich.

WALTERS

TOBEY

MARIAN

WOOD PRESERVATION

Monday, June 29, 2:00–4:30 p.m.

Presiding Chairman: Chas. S. Walters, University of Illinois, Urbana, Ill.

Development of Fire-Retardants for Wood Treated with Oil-Type Preservatives. H. M. Tobey, Chapman Chemical Co., Memphis, Tenn.; R. M. Gooch & D. L. Kenaga, Dow Chemical Co., Midland, Mich.

Flame-Spread Measurements on Wood-Base Materials Using Radiant Panel Test Method. Daniel Gross, U.S.D. Commerce, National Bureau of Stand-

ards, Washington, D. C.
Prevention of Deterioration of Wood in Contact with Iron. J. E. Marian, Calif. Forest Products Lab., Richmond, Cal. and Arne Wissing, Swedish Forest Products Lab, Stockholm.
Building Codes as they Relate to Forest Products, by John Fies, NLMA, San Francisco.

DAVIES ANDREE MILES

LOGGING

Tuesday, June 30, 9:30–11.30 a.m.

Presiding Chairman: Emanuel Fritz, U. of Calif., Berkeley, Cal.
Recorders: Fred Nord and Wm. Brubaker, California Redwood Assoc., San Francisco.
Harvesting Small Logs in Douglas Fir Region. W. A. Davies, Ore. State College, Corvallis, Ore.
Bacterial Attack of Pine Logs in Pond Storage. Eric Ellwood & B. A. Ecklund, Calif. Forest Products Lab., Richmond, Cal.
Peeler Procurement, Handling and Storage Problems in Northern California, R. C. Andree, U. S. Plywood Corp., Redding, Cal.
Salvage Logging. John Miles, Simpson Redwood Co., Arcata, Calif.

ELLWOOD NORRIS STUTZ

WOOD DRYING

Tuesday, June 30, 9:00–11:30 a.m.

Presiding Chairman: Eric Ellwood, Calif. Forest Products Lab., Richmond, Cal.
Recorder: R. W. Erickson, University of California, Richmond, Cal.
The Transverse Anisotropy of Wood as a Function of Gross Anatomic Structure. A. P. Schniewind, Calif. Forest Products Lab., Richmond, Cal.
Air Circulation in Forced Air Drying of Lumber. D. M. Post, U. of Fla. Gainesville, Fla.
Solvent Seasoning of Tanoak. A. B. Anderson & W. B. Fearing, U. of Calif., Berkeley, Cal.
Calculating Internal Stresses in Wood. R. L. Youngs & C. B. Norris, Forest Products Lab., Madison, Wis.
Control of Sugar Pine Brown Stain with Sodium Azide. R. E. Stutz, Western Pine Assn., Portland, Ore.

LAUGHNAN ALLYN DRUBEL

WOOD FINISHING

Tuesday, June 30, 9:00–11:30 a.m.

Presiding Chairman: Don Laughnan, Forest Products Lab., Madison, Wis.
Acrylic Finishes for Exterior Wood Surfaces, by Gerould Allyn and J. Richardson, Rohm & Haas, Philadelphia.
Fire-Retardant Latex Intumescent Coatings. Richard Drubel, Dow Chemical Co., Midland, Mich.
Alcohol & Solvent Resistant Furniture Finishes. Robert L. Skov, Hercules Powder Co., Wilmington, Del.
Polyurethane Wood Finishes. L. L. McGinnis, E. I. du Pont de Nemours & Co., San Francisco, Cal.
Polyester Wood Finishes, Neil Estrada, Reichhold Chemicals, Inc., San Francisco, Cal.
Developments in Color Finishing for Plywood—Precolor Sealing System & Rollgrain Printing. P. E. Leary, Wolverine Finishes Corp., Grand Rapids, Mich.
Epoxy Resins for Wood Finishing, by H. W. Howard, Shell Chemical Corp., New York City.

STERN McRAE SWANSON

PACKAGING

Tuesday, June 30, 2:45–5:15 p.m.

Presiding Chairman: Karl Bollerslev, Boise-Cascade Corp., Boise, Idaho.
Recorder: John K. Martin, Pacific Lumber Co., Scotia, Cal.
What's New in Pallet Assembly. E. G. Stern, Va. Polytechnic Institute, Blacksburg, Va.
Pallet Bins for Harvesting Apples in Pacific Northwest. S. W. McBirney, USDA, Tree Fruit Exp. Sta., Wenatchee, Wash.
Spiral Wrapping Machine for Panel Products. R. C. McRae, Coast Iron & Machine Wks., Tacoma, Wash.
Engineered Wood Cellulose Cushioning for Packaging. C. E. Swanson and A. J. Withoff, Wood Conversion Co., St. Paul, Minn.

MATER WINER SHELTON

LUMBER MANUFACTURING

Tuesday, June 30, 2:45–5:15 p.m.

Presiding Chairman: Milton Mater, Mater Engineering Co., Corvallis, Ore.
Recorder: Paul Heller, Pacific Pine Co., New Westminster, B. C.
Place of the Sawmill in an Integrated Forest Operation. L. W. Hooker, Mich. College of Mining & Tech., Houghton, Mich.
Place of the Sawmill in a Predominately Douglas Fir Integrated Forest Operation. D. E. Lane, B. C. Forest Products Ltd., Vancouver, B. C.
Sorting Logs to Improve Sawmilling. H. I. Winer, Yale Univ., New Haven Conn.
Integration of the Lumber Mill from Wood to the Car Door. N. T. Shelton, Diamond Match Co., Chico, Cal.

LUBECK McGINNIS BENNETT

WOOD FINISHING

Tuesday, June 30, 2:45–5:15 p.m.

Presiding Chairman: Donald Lubeck, Hammond Organ Co., Chicago, Illinois.
New Processing Methods:
Controlled Temperature—Low Pressure Spray. Harold Fornwall, The DeVilbiss Co., Toledo, Ohio.
Airless Spray. Edwin Hogstrom, Nordson Corp., Amherst, Ohio.
Steam Spray. L. L. McGinnis, E. I. du Pont de Nemours & Co., Wilmington, Del.
Hydra-Spray. D. A. Koch, Grayco Prod. Co., Minneapolis, Minn.
George Knetl, Binks Mfg. Co., Chicago, Ill.
Automatic Spraying Techniques.
Catalyst Spraying Techniques. H. Fornwall, DeVilbiss Co., Toledo, Ohio.
Pressure Curtain Coaters. R. L. Campbell, Wilco Machine Works, Memphis, Tenn.
Electrostatic Spraying. E. P. Mill[illegible], Ronsburg Electro-Coating Corp., I[illegible]dianapolis, Ind.
Roll Coating. R. R. Teasdale, Gasw[illegible] Corp., Chicago, Ill.
Flowcoating & Dipping. O. L. W[illegible] the Spra-Con Co., Chicago, Ill.
Infra-Red Drying. I. J. Barber, F[illegible]

toria Pressed Steel Corp., Fostoria, Ohio.

Sanding Techniques. H. L. Bennett, Behr–Manning Corp., Troy, N. Y.

ANDERSON

IVORY

ESPENAS

LUMBER MANUFACTURING & WOOD DRYING

Wednesday, July 1, 9:00–11:30 a.m.

Presiding Chairman: Paul Heller, Pacific Pine Co., New Westminster, B. C.

Recorder: Eric L. Ellwood, Calif. Forest Prod. Lab., Richmond.

Some Problems in Effectively Using Results of Research in Lumber Manufacturing & Drying. C. F. Anderson, Winton Lumber Co., Minneapolis, Minn.

Segregation of Lumber for Kiln Drying. K. O. Smith, Jr., Cheney Lumber Co., Tacoma, Wash.

Recent Research Results & Their Application in the Lumber Industry. Leif Espenas, Ore. Forest Products Research Center, Corvallis, Ore.

Lessons Learned in the Construction and Operation of Internally-Fired Kilns. E. P. Ivory, Ivory Pine Co., Dinuba, Cal.

Automated Sorting & Stacking of Green Lumber in a Small Mill. Charles Herstrom, Powell River Co., Ltd., New Westminster, B. C.

Effect of Weighting Lumber Piles, by Edward Conway, Lumber Drying Specialty Co., Grand Rapids, Mich.

BRYANT

RAYMOND

PATRONSKY

GLUES & GLUING

Wednesday, July 1, 9:00–11:30 a.m.

Presiding Chairman: Ben S. Bryant, University of Washington, Seattle, Wash.

Recorder: Ray A. Currier, Oregon Forest Products Research Center, Corvallis, Ore.

Panel discussion: "How Can the Plywood Industry Improve Control of its Glue-Bond Quality?"

Responsibility of the Trade Assn. to the Industry. R. C. Raymond, Douglas Fir Plywood Assn., Tacoma, Wash.

The Adhesive Companies' Role in Assuring Quality Glue Bonds. J. M. Hine, Borden Co., Seattle, Wash.

Quality Control—A Production Responsibility. K. K. Graves, Georgia–Pacific Corp., Portland, Ore. The Plywood Manufacturer's Unique Responsibility. H. W. McClary, Simpson Logging Co., Shelton, Wash.

Quality Control—A Customer's Privilege. L. A. Patronsky, Timber Engineering Co., Albany, Ore.

WELCH

GLOSS

WILLIAMS

INDUSTRY–EDUCATION

Wednesday, July 1, 9:00–11:30 a.m.

Presiding Chairman: W. E. Welch, Timber Structures, Inc., Portland, Ore.

Recorder: W. I. West, Oregon State College, Corvallis, Ore.

The Lumber Industry's Stake in Education, R. H. Gloss, Timber Engineering Co., Washington, D. C.

An Architect's Use of Wood. Henry Hill—Architect, San Francisco, Cal.

Education Sells Wood Structures—A Company's Experience. G. A. Williams, St. Paul & Tacoma Lumber Co., Tacoma, Wash.

Objectives of NLMA's Education Program. John I. Zerbe, NLMA, Washington, D. C.

LLOYD

FITZPATRICK

BISHOP

MERCHANDISING

Thursday, July 2, 9:00–11:30 a.m.

Presiding Chairman: W. B. Lloyd, Michigan State Univ., E. Lansing, Mich.

Recorder: K. R. Peterson, U. of Illinois, Urbana.

"Wood's Promotion—Whose Responsibility?" Viewpoint of the Lumber Retailer, Albert B. Ratner, Forest City Material Co., Cleveland, O.

What Wholesalers are Doing to Promote Wood and Wood Products, by L. J. Fitzpatrick, J. J. Fitzpatrick Lumber Co., Madison, Wis.

Viewpoint of Lumber Manufacturer. S. A. Bishop, Union Lumber Co., San Francisco, Cal.

Panel Discussion (above three authors)

Presentation: Hitchcock's Wood Working "Award of Merit". Robert Bolinders, Wheaton, Ill.

HARRIS

WITHER

PEARL

CHEMICAL UTILIZATION

Thursday, July 2, 9:00–11:30 a.m.

Presiding Chairman: Winton I. Patnode, Consultant, Tacoma, Wash.

Recorder: J. Elton Lodewick, Longview, Wash.

A Summary of the Status of Pyrolysis. R. C. Sproull, Philip Morris, Research Department, Richmond, Va.

Preparation and Properties of Hydroxymethyl furfural. J. F. Harris, L. L. Zoch, and J. F. Saeman, U. S. Forest Products Laboratory, Madison, Wis.

Pulping Characteristics of Sawdust Chips Made by a Coarse Feed Saw. J. S. Martin, U.S. F.P.L., Madison.

Laboratory Evaluation of Nitric Acid Pulping. Ross P. Wither and Henry Captein, Crown Zellerbach Corporation, Camas, Wash.

Separation of Lignosulfonates from Carbohydrates in Aspen Spent Sulfite Liquors by Means of Ion Exchange. Irwin A. Pearl and Donald L. Beyer, Institute of Paper Chemistry, Appleton, Wis.

COCKRELL

BESCHER

DARGAN

GENERAL

Thursday, July 2, 9:00–11:30 a.m.

Presiding Chairman: R. A. Cockrell, U. of Calif., Berkeley, Calif.

Recorder: F. J. Rovsek, Madison, Wis.

Process of Converting Sawdust to an Efficient Fertilizer Carrier/Soil Conditioner. Eduard Farber, Timber Engineering Co., Washington, D. C.; R. R. Hind, Pope & Talbot, Inc., & Fersolin Corp., San Francisco, Cal.

Merchandising Aspects of "Non-Com". R. H. Bescher, Koppers Co., Inc., Pittsburgh, Pa.

Effect of Formation Variables on Properties of Wood Particle Moldings. T. J. Patterson, Georgia-Pacific Corp., Hillsboro, Ore.; & J. D. Snodgrass, Ore. Forest Products Research Center.

Continuous Carbonization & Briquetting of Wood Residue. E. E. Dargan, Charcoal Industries, Inc., Conway, S. C., & W. R. Smith, USDA, Div. Forest Util. Research, Asheville, N. C.

Study of Means for Reducing Checking of Douglas-Fir Plywood Without Overlays or Sealers. Armin Elmendorf, Elmendorf Research, Inc., Palo Alto, Cal.

MOTTET HEEBINK MAXWELL

WOOD COMPOSITION BOARD

Thursday, July 2, 2:00–4:30 p.m.

Presiding Chairman: A. L. Mottet, International Paper Co., Long-Bell Division, Longview, Wash.

A Great Challenge to the Particle Board Industry—Develop Standards. K. W. Guenther, Pope & Talbot, Inc., Oakridge, Ore.

Bending Strength of Wood Particle Board Under Long Term Loading. Eugene Bryan, Calif. Forest Products Lab., Richmond, Cal.

Stability & Strength of Oak Particle Boards as Influenced by Particle Shape and Inclusion of Wax. Bruce Heebink, Forest Products Lab., Madison, Wis.

Adhesives for the Manufacture of Particle Board. J. W. Maxwell, Geo. Kitazawa, T. F. Duncan and J. M. Hine, The Borden Co., Seattle, Wash.

WYLIE STUMBO BETHEL

QUALITY CONTROL

Thursday, July 2, 2:00–4:00 p.m.

Presiding Chairman: A. E. Wylie, Mich. State Unv., E. Lansing, Mich. Recorder: Robert Gilmore, North Carolina State College, Raleigh, N. C.

Methods & Machines for Quality Control of Forest Products. O. J. Black, I. B. M. Corp., New York, N. Y.

Usefulness of Surface Texture Measurements for Quality Control. D. A. Stumbo & J. E. Marian, Calif. F.P.L.

Linear Programming in Sawmill Operations, J. S. Bethel, Geo. Smith and Norman Jackson, N. C. State College, Raleigh, N. C.

Veneer & Plywood

A NEW PERFORMANCE TEST FOR INTERIOR PLYWOOD AND ITS APPLICATION TO PANELS CONTAINING WHITE POCKET

The proposed use of white pocket infected Douglas fir veneer in standard grades of Interior type panels has posed a glueability question. Previous work has shown that this class of veneer can be difficult to glue adequately unless the best of adhesives were employed. Recent and exhaustive experiments utilizing the new Interior test show that the cold press process, using adhesives currently available, will encounter considerable difficulty in meeting glueline quality requirements. The hot press process using adequate adhesives does satisfactorily bond this material.

Abstracts from Selected National Meet Papers

(See Technical Program, Preceding Pages, for Authors and Times)

LATHE CHECK FORMATION IN DOUGLAS FIR VENEER

High speed motion pictures at approximately 6000 frames per second of the veneer cutting process with a roller bar production lathe are shown. Discussion of space and time details near the cutting edge is given, followed by an analysis of the effect of production variables, nosebar pressure and cutting speed, on veneer smoothness, thickness and percent depth of lathe checks.

MOTION PICTURE STUDIES OF VENEER CUTTING AT CELLULAR LEVEL

With a few preliminary remarks about equipment used and what to look for, the motion picture will tell much of its own story. Titles will tell the necessary information about each sequence. The pictures will show how the cell structure is deformed by the knife and the nosebar. The results of a dull knife will be seen.

HEATING DOUGLAS FIR VENEER BOLTS—DOES IT PAY?

Veneer production from cold blocks of two grades with that from matched blocks heated prior to peeling was compared. All of the hot-peeled and cold-peeled veneer was dried, tallied by grade, and weighed. Preheating provided a substantial increase in the percentage of 'A' grade veneer recovered; 60 per cent as contrasted to 48 per cent from cold No. 2 peelers, and 17 per cent compared to 11 per cent from cold No. 4 peelers. Loss of 'A' grade veneer in cold peeling was due to increased splitting and to a roughened peel in some blocks. Based on the best available method of calculating veneer values, relative worth of veneer from hot-peeled blocks was $5 and $14 a thousand board feet (net log scale) higher than that from cold-peeled No. 2 and No. 4 blocks, respectively. Additional investment and operating costs of presteaming Douglas fir veneer logs are estimated to be $0.82 a thousand board feet, net log scale.

Wood Machining

CROSS-CUTTING RESEARCH WITH POWER SAW CHAIN TEETH

There is an extreme scarcity of published information on cross-cutting under controlled conditions similar to those used in harvesting trees with chain saws. An extensive program has been completed using various saw chain teeth mounted on a large circular disc driven by a reliable dynamometer. Means were developed to obtain comparative ratings of cutters over a wide range of conditions. Results obtained point the way for future improvements in saw chain cutter performance.

PERFORMANCE CHARACTERISTICS OF COMBINATION CIRCULAR SAWBLADES ON RADIAL ARM SAWS

Four combination-type sawblades, three wood species, and four feed rates are studied for each of three cutting directions. These are ripsawing, 45° miter sawing and crosscutting. The latter two are performed by climb sawing, as usual for radial arm saws. All other cutting variables, such as depth of cut, moisture content and blade protrusion are held constant. The data were obtained using a 7½ hp radial arm saw equipped with an air-hydraulic feed system. Basic feed rate vs. net cutting power curves are given for each combination of sawblade, cutting direction and species.

Glues & Gluing

TECHNOLOGY OF ELASTOMERIC ADHESIVES

Elastomeric adhesives accommodate adherends with widely differing expansion-contraction behaviors, and so can be formulated to produce bonds upon contact, freeing the user from the need to furnish pressure for more than a momentary period. At least four basic types are in use. As a group and with some very notable exceptions, they are not given to fast cures. They are poor in creep resistance and high in impact loading resistance. They are almost unique in that every minute they are bonded the bond is stronger than it was the minute before. They fill an important need, but they often suffer from misapplication.

FINGER JOINTING AT HIGH MOISTURE CONTENTS

The upper limit of wood moisture content for gluing with standard wood adhesives seldom exceeds 15 per cent, according to most glue manufacturers' instructions. Object of present research was to evaluate end-glued joints in Douglas fir 2- by 4-inch lumber at moisture contents ranging from 8 to 22 per cent. Two different types of end joints were prepared, a scarf joint with 1:6 slope and a standard production-type finger joint. Scarf joints were glued with a phenol-resorcinol adhesive; finger joints were glued with phenol-resorcinol and melamine-urea adhesives. End-glued studs were evaluated by determining moduli of rupture and elasticity.

Chemical Utilization

THE INFLUENCE OF EXTRACTIVES ON THE SEASONING STAIN OF REDWOOD LUMBER

Redwood extractives may account for 15 to over 30 percent of the total weight. The greater portion of this extract is water soluble, and consists largely of tannins with smaller quantities of cyclitols and simple sugars. The tannin is very sensitive to heat, light, humidity and oxygen—all of which cause it to darken and gradually become insoluble in water.

A study of the distribution of extractives before and after kiln drying showed a little over twice as much water-soluble extractives deposited in the outer layer as in the inner core of the board. The over-all appearance of redwood boards can be governed somewhat by kiln conditions. High temperatures produce darker boards while the lower temperatures generally produce the lighter-appearing boards.

WOOD AND BARK PRODUCTS USED IN OIL WELL DRILLING

Drilling fluids or muds are highly important in drilling operations and many thousands of dollars are generally invested in the mud for each well drilled. The forest products industry has contributed to improved drilling mud additives. Quebracho, itself a wood derived tannin, was the forerunner of a number of mud chemicals. Today useful additives are manufactured from redwood and hemlock bark, paper mill wastes, and several other sources. Other tree-derived products ranging from sawdust through selected fibers from bark and wood and on to such derivatives as cellophane are commonly used to stop loss of drilling mud to faults in the earth as the drill bit penetrates various earth formations.

AN INTEGRATED TIMBER STAND IMPROVEMENT-CHARCOAL KILN OPERATION

A masonry block charcoal kiln was constructed and operated on the Upper Peninsula Forest to determine break-even costs. The costs of construction and operation of the kiln are discussed as well as the logging operation in second-growth northern hardwood timber. Most of the 2 million acres of second-growth hardwood timber in the Upper Peninsula of Michigan is badly in need of improvement and thinning cuts. By using a charcoal kiln to utilize the nonmerchantable wood, it was found that the timber stand improvement job could break even if labor costs were $1.47 per hour and the bulk charcoal could be sold at $55 per ton loaded on trucks at the kiln site.

Wood Preservation

DEVELOPMENT OF FIRE RETARDANTS FOR WOOD TREATED WITH OIL-TYPE PRESERVATIVES

Since 1953 Dow Chemical and Santa Fe Railroad have conducted a joint research program aimed at combating flash fires in treated timber trestles. Early work showed that the addition of halogenated organic phosphorus compounds to the common oil-type preservatives provided measurable control. When materials of this type were found to be hydrolytically unstable, interest was directed to the aromatic phosphate esters. Field tests were expanded to include a series of full-scale bridge replica fires following which a commercial development program on the phosphates was initiated by Dow. The work to date indicates that commercially practical fire retardant systems are available for use with oil-type preservatives.

FLAME-SPREAD MEASUREMENTS ON WOOD-BASE MATERIALS USING THE RADIANT PANEL TEST METHOD

The results of a limited number of tests for evaluation of the flame-spread retardancy of surface coatings applied to wood-base materials is presented. The correlation of results of the radiant panel and other test methods and its usefulness for rapid evaluation of retardant coatings is demonstrated. Research into the mechanisms of fire-retardancy and the development of new, practical fire-retardant treatments is suggested.

Logging

SMALL LOG HARVESTING IN THE DOUGLAS FIR REGION

Small logs form an important and expanding source of wood in the Douglas-fir region. These logs come primarily from thinnings, pre-logging and salvage, with thinnings from young stands offering the best possibility for greatly increased volume. Some of the problems of thinning and salvage logging are: Development of new logging methods and equipment to efficiently handle small logs, especially on steep areas. Access to the stands. An understanding, by the forest owners, of the possibilities of utilizing the small logs. Availability of local markets for the logs.

BACTERIAL ATTACK OF PINE LOGS IN POND STORAGE

Describes the nature of such attack, the problem of porosity, and results of investigations on the identification of the causative organisms and methods of controlling them. The results of a survey in California on the extent of the problem and the implications with respect to log storage are discussed.

Wood Drying

AIR CIRCULATION IN FORCED AIR DRYING LUMBER

Air seasoning is the oldest and most used method of drying lumber. Forced air drying is basically air seasoning accelerated by the use of fans to insure positive circulation. With the proper use of fans air seasoning time can be reduced 75% or greater under good conditions. This paper deals with the fundamental data necessary to design an efficient forced air dryer. Results of tests show that using slow air velocities are much more economical as to power costs, air leakage loss problem, stacking arrangement problems, uniform distribution and more efficient use of the air, although a sacrifice in drying time occurs.

CALCULATING INTERNAL STRESSES IN WOOD

A method of calculating the perpendicular-to-grain normal and shear stresses at any point on the cross section of a board, and that can be applied at any stage of drying or after drying has been completed. The results appear to indicate quite satisfactorily the magnitude and distribution of normal and shear stresses at the stage of drying considered.

SOLVENT SEASONING OF TANOAK

The three major hardwoods of California from volume standpoint are tanoak, California black oak, and Pacific madrone, totaling some five billion board feet. All attempts to manufacture and market lumber from these species have generally failed. The solvent seasoning process has been applied to tanoak. The lumber so processed is relatively free of seasoning defects and has a lighter appearance than conventionally dried tanoak. The commercial feasibility of this process for drying this hardwood will be considered.

CONTROL OF SUGAR PINE BROWN STAIN WITH SODIUM AZIDE

The chocolate colored brown stain found in Sugar Pine has been shown to be caused by a naturally occurring enzyme which can be inhibited with a buffered dip solution containing 0.5 lb. of sodium azide per 100 gallons. A $15–20 per M.b.f. saving can be realized. The lighter colored brown stain in Idaho White Pine can be inhibited with azide. The coffee stain of Eastern White Pine should be controllable as may also be the tannin forming stains of Redwood and some of the southern hardwoods.

Wood Finishing

LATEX FIRE RETARDANT INTUMESCENT COATINGS

The development of factory applied latex bound intumescent coatings supplies an effective means of imparting fire protection to low density woodfiber wallboard and acoustical tile. In comparison to proprietary intumescent coatings, the latex bound systems offer significant improvements in humidity and scrub resistance and are readily utilized on commercial coating equipment.

NEW FINISHES FOR WOOD—POLYESTER TYPES

Polyester resins, firmly established in reinforced plastics and in surfacing applications, are receiving belated attention as coating materials, particularly as wood finishes. Most of the continued growing interest in polyester wood finishes is for "hard-to-coat" materials, such as particle board, to provide "one-coat" finishes where present solvent-based coatings are inadequate, for "plastic-faced" surfaces where hot-pressed laminations are cumbersome and much more costly, and for coatings requiring exceptional resistance to solvents, moisture and many chemicals.

COLOR FINISHING FOR PLYWOOD—THE PRECOLOR SEALING SYSTEM AND ROLLGRAIN PRINTING

Two fundamental finishing systems which are contributing to increased color consciousness and broader marketing in the wood industry are precolor sealing and rollgrain printing. In the performance of a precolor-sealing operation the two fold task of color adoption to wood and the foundation coat, or seal coat, application is accomplished; thereby preparing plywood flat stock for subsequent, final finish. The rollgrain print system is the method whereby foundation woods such as poular, fir, gum veneer, etc, as well as hardboard, and flakeboard are converted by finishing materials into surface patterns simulating finer woods for cabinet making, paneling, even casegoods furniture.

EPOXY RESINS FOR WOOD FINISHING

Epoxy resins, which have been marketed to prime paint, varnish, and lacquer manufacturers for some 12 to 14 years, have gained acceptance in practically all coating fields with the exception of wood finishing. These resins are normally characterized by oustanding chemical resistance, adhesion, flexibility, and toughness. They adhere exceptionally well to practically all surfaces. They may be blended with

any other film formers and impart important characteristics unobtainable by other materials to these. In the field of wood finishing there are three ways in which epoxy resins will be suggested. A display of panels using all three systems will accompany the talk

ACRYLIC FINISHES FOR EXTERIOR WOOD SURFACES

Acrylic emulsion paints are being used in increasing quantities on exterior wood surfaces such as clapboards, wood trim and wood shingles and shakes, because of their ease of application, fast drying speed, excellent blister resistance, color retention and long term durability outdoors. Five year laboratory controlled exposures and commercial paint jobs are giving excellent outdoor durability on wood surfaces in many parts of the United States and Canada. Much research has gone into the development of suitable formulations for acrylic emulsion paints on wood. For best results, it is essential that low pigment volume content formulations be used with maximum solids content. Variations in chalk rates needed for Northern or Southern climates can readily be achieved through differences in pigmentation.

WHY POLYURETHANE COATINGS FOR WOOD

Outstanding toughness and abrasion resistance of these coatings are real advantages in finishes for wood. Two package systems with short "pot life", color retention, pigmentation problems and toxicity are problems that limit utilization. It is expected that Polyurethanes will be used for special applications.

Packaging

PALLET BINS FOR HARVESTING APPLES IN THE PACIFIC NORTHWEST

Pallet bins for harvesting and handling apples and other fresh fruit are coming rapidly into commercial use in fruit growing areas. Approximately $1,500,000 has been spent for fruit harvesting bins in Washington alone, nearly all in 1958. These bins mostly have been of about 25-box capacity, but there has been little standardization of size or design. Bins have to support loads of up to five tons in cold storage, but not much is known of strength needed to withstand usual orchard handling or what is an economical design. Bin costs range from around $7 to $13 each. Present plans indicate that the number of bins in use will more than double in 1959.

WHAT'S NEW IN PALLET ASSEMBLY

Part I of this study indicates that the conventional, 2½" x 0.120", helically threaded, "stiff-stock" pallet nail, used for fastening hardwood deckboards to hardwood stringers, may be replaced with a 24 percent lighter, 2¼" x 0.110", hardened nail with an especially effective helical thread. This improved nail (a) requires one quarter less pounds of nails per pallet, without reducing the number of nails, (b) can be driven easier and faster, hence, allows faster pallet assembly, (c) effectively reduces lumber splitting, and (d) provides a pallet with the same or almost the same rigidity and resistance to diagonal forces. Part II reveals that the use of a properly threaded and hardened nail with a well shaped blunt chisel point can be sanctioned for pallet assembly. Such a nail appears to provide the same or only slightly smaller effectiveness than the conventional pallet nail with medium diamond point; however, it significantly reduces the occurrence of end splits of deckboards.

A SPIRAL WRAPPING MACHINE FOR PANEL PRODUCTS

This machine was developed to wrap bundles of plywood panels in Kraft paper. It employs an unusual method to achieve a neat and tight protective package, automatically, and at a rate equal to the output of a packaging department employing ten men hand-wrapping the panels.

Lumber Mfg.

SORTING LOGS TO IMPROVE SAWMILLING

Simple forms of log sorting are often found in American operations, usually to separate logs destined for different products. However, sorting sawlogs may also create an optimum flow of materials to different headrigs and auxiliary breakdown equipment within a sawmill or group of sawmills. Scandinavian countries have led the way in sorting sawlogs to achieve the highest possible yields of gangsawing. A survey of current American practice shows that sorting is increasing in the woods, at intermediate storage and landing areas, and especially at the mill itself. Here recent developments in cheap, flexible, and efficient log handling machines have favored sorting on land, rather than in the mill pond. The benefits to be achieved are varied: simplification of inventory and production-control problems and the reduction of lumber sorting costs.

PLACE OF THE SAWMILL IN AN INTEGRATED FOREST OPERATION

More and more products made by reducing wood to small particles and re-assembling those particles to produce materials engineered for specific uses, the tendency is to look upon the sawmill as becoming obsolete. The sawmill will continue to be an important factor in integrated forest operations, but a different concept of its role must develop. Instead of being regarded as the prime factor in conversion of trees, producing boards and "waste" products, it must be looked upon as a primary break-down plant, where trees are first cut up into portions which will then be sorted and diverted to further manufacturing and refining processes.

Lumber & Drying

ROLE OF THE SAWMILL IN WHOLE LOG UTILIZATION

The case history of a fully integrated forest products center; the planning which preceded the construction of the plant to obtain maximum utilization of the timber resources and the end use of the log in the form of lumber, lumber products, groundwood pulp, molded pulp products and fuel for generating process steam and the research now underway for more intensive utilization of the sawmill residuals.

EFFECTIVELY USING THE RESULTS OF RESEARCH IN LUMBER MANUFACTURING AND DRYING

There exist some problems, from the point of view of management, in effectively using the fruits of research. 1) Problems that apply to firms whose use of research is in the field of product development. 2) Problems that apply to firms who will use, in the course of manufacturing their own products, the new products developed by others. In the case of product development, the researcher is much more motivated by th knowledge he amasses for knowledge's sake alone than by the sales potential of the new product. On the other hand, the marketing man is motivated in just the reverse fashion. Here is a conflict that stifles the effective use of research. What are some of the techniques or methods being proposed or tried by management to make more effective use of research? Is there a possibility of successful application of these techniques by a lumber-oriented management?

SEGREGATION IN THE DRYING OF WESTERN WOODS

Segregation for optimum drying consists of sorting lumber into separate units or kiln charges that should receive the same treatment during the drying process. Advantages are: 1) More uniformly dried lumber. 2) Shorter drying time in the kiln. 3) Less kiln caused degrade. 4) Lower kiln costs per M.B.F. 5) Facilitates drying to a final moisture content for a specific end use. Disadvantages: 1) Setting up the facilities for sorting. 2) Costs of sorting. 3) Flexibility of kiln capacity. 4) Mill production or volume of lumber for segregation.

Glues & Gluing

HOW CAN THE PLYWOOD INDUSTRY IMPROVE CONTROL OF GLUE BOND QUALITY?

Management's full acceptance of its moral responsibility to customers and a reanimation of its business integrity creates the only sound basis for positive quality maintenance and improvement. Control must emanate from within an organization and be strengthened through development of qualified technical mill personnel. The manufacturer's "unique" responsibility is "full" responsibility.

GLUE BOND QUALITY—THE RESPONSIBILITY OF THE TRADE ASSOCIATION

The remarks are confined to the Douglas Fir Plywood industry. While the real responsibility for maintenance of glueline quality lies with the mill the D.F.P.A. assists in every possible way in technical matters related to quality. Its quality control program includes an adequate sampling of each member's mill's production, testing samples in accordance with established test methods, reporting test results to the mill and keeping necessary records to determine conformance with standards. Members are kept advised of factors which affect their glueline quality

IMPROVED CONTROL OF GLUE-BOND QUALITY

The goal of quality control in plywood is to provide the consumer wit

an adequate product which is consistently uniform and well manufactured at a price that allows an efficient producer a reasonable profit margin under normal marketing conditions. A delicate balance exists between customer and producer which can be maintained only by means of implicity definitive product specifications and standards enforced strictly and equitably.

Education

THE LUMBER INDUSTRY'S STAKE IN EDUCATION

The basic problem is one of attracting men to be educated. Judging by present conditions, either the "image" of the industry is poor or there has been almost complete lack of selling the image to young men. Obviously the immediate starting point must be in selling the industry at high school level. But equally important is the need to attract those already being trained whose knowledge is equally needed in the wood-industries; engineers, chemists and physicists to name but three. The problem is a great deal more than forestry or utilization graduates.

Chemical Utilization

PULPING CHARACTERISTICS OF SAWDUST CHIPS MADE BY A COARSE-FEED SAW

The short fiber lengths resulting from sawdust particles of widely varying size have been a major obstacle in the use of sawdust for pulp. A recent development of a primary breakdown saw produces sawdust chips having a fiber length that is suitable for pulping and may be potentially acceptable for the manufacture of pulp. The Forest Products Laboratory has undertaken tests with this type of saw in which various tooth forms, including standard stock teeth, are being tried. This study will include determination of the character of the board surface, accuracy of sawing, saw speed, feed rates, and the character of the sawdust particles developed. Sulfate pulping tests on chips produced with a 12-tooth saw having an average length of 1/4 inch in the fiber direction, and retained on a 3/16-inch mesh screen, gave pulps having about 85 percent of both the bursting strength and tearing strength of pulps produced from conventional chips.

LABORATORY EVALUATIONS OF NITRIC ACID PULPING

In recent years the increasing availability of ammonia at lower cost and the greater utilization of previously wasted wood has caused renewed interest in the nitric acid pulping process. An evaluation of the suitability of this pressure-free process for the pulping of Western softwoods and sugarcane bagasse was carried out in the laboratories of the Crown Zellerbach Corporation. The strengths of pulps produced by nitric acid were in general lower than those of sulfite pulp, but bagasse pulp produced by nitrogen dioxide was comparable in strength to kraft bagasse pulp. In each case, the high consumption of nitric acid made the process too costly to be acceptable as a commercial operation. By-products of the process, emphasis on the effect of tool wear and damage.
known to include acetic and oxalic acids, were not found in sufficient quantity to warrant recovery study.

General Session

PROCESS OF CONVERTING SAWDUST TO AN EFFICIENT FERTILIZER CARRIER/SOIL CONDITIONER

The Farber patents developed at the Timber Engineering Company, describe a catalytic process for producing a chemical condensation of the cellulose components of wood. For carrying out this process, a new continuous method has been developed by Pope & Talbot and its associate company, Fersolin Corporation. The method consists in carrying sawdust, admixed with catalysts, through a hot zone for the condensation reaction, then neutralizing and loading the product with ammonia, and conditioning it. Extensive testing during several years has shown that the product has characteristic beneficial effects on soils and plant growth. A new method for the large-scale utilization of sawdust has thus been developed.

CONTINUOUS CARBONIZATION AND BRIQUETTING OF WOOD RESIDUE

A long time dream of a continuous process for carbonizing sawdust, bark, and other wood residue has become reality. Through a process invented by Svend Thomsen, Conway, South Carolina, wood residue is carried inside tubes through a heated chamber at temperatures of 800°–1000°F and emerges fully carbonized. The carbonized residue is cooled by steam, sprayed with a starch binder, and immediately introduced to a patented briquetting machine and compressed while still at a temperature of about 200°F. Very soon after briquetting and with no artificial drying, the charcoal briquettes are dry enough to package. Operating costs, production rates, and yields will be presented. The process and equipment will be made available soon, probably on a lease and royalty basis.

Composition Board

BENDING STRENGTH OF WOOD PARTICLE BOARD UNDER LONG-TERM LOADING

When subjected to long-term loads, most types of building material will fail at a stress level considerably below the strength of the material as determined by standard testing methods. It is therefore important to take this phenomenon into consideration when calculating the allowable working stresses for materials which will be subjected to this type of loading. If long-term loading information was available for wood particle board, its use as subflooring and other structural components would be more readily advanced. This study was made to investigate some aspects of the long-term loading characteristics of particle board in order to furnish some of the much needed information. Although wide scatter in the data made it impossible to establish precise relationships, it appeared that the board types investigated are similar to whole wood with respect to the properties considered.

THE EFFECT OF FORMATION VARIABLES ON THE PROPERTIES OF WOOD PARTICLE MOLDINGS

A laboratory experiment is described that explored independent and interrelated influences of particle size, resin content, pressure, and moisture on certain properties of wood-particle moldings having a relatively simple dish shape. Synthetic resin not in excess of 15 per cent, Douglas fir wood particles from 10 to smaller than 40 mesh, and pressure up to 1500 psi were used to produce the molded dishes. The design involved 3 levels of each variable, or 81 combinations; there were 4 replications. Results from 5 types of physical tests of moldings were analyzed statistically.

STABILITY AND STRENGTH OF OAK PARTICLE BOARDS AS INFLUENCED BY PARTICLE SHAPE AND INCLUSION OF WAX

The primary purpose of the work was to determine the effect of particle shape and inclusion of wax on the dimensional changes of the boards when exposed to equilibrium conditions at various relative humidities. Secondary objections were the effect of different particle shapes on strength properties and amount of fines produced. Test results showed that boards made with 1-inch-long flakes were the strongest in all respects and the most stable linearly, followed by boards made from 1/4-inch-long flakes, planer shavings, slivers, fines, and sawdust. The addition of 1 percent of wax to the boards had no appreciable effect on dimensional stability or on strength; however, it did greatly retard the rate of liquid water absorption. The percentage of fines was approximately 7 percent for 1-inch-long flakes, 9 percent for shavings, 10 percent for 1/4-inch-long flakes, 21 percent for slivers, and 73 percent for sawdust.

Quality Control

METHODS AND MACHINES FOR QUALITY CONTROL OF FOREST PRODUCTS

The statistical methods applicable to quality control of forest products are surveyed, and the role of calculators and computers in implementing these methods is described. In particular, multiple regression analysis is considered, and it is demonstrated that electronic computation is necessary to obtain the advantages of such analysis. An example is given of a regression problem solved by an intermediate-size electronic computer—the IBM 650. By means of an ingenious stored program, the computer provides successive regression equations, beginning with the most important independent variable and adding independent variables, one by one, until the remaining ones are insignificant.

THE USEFULNESS OF SURFACE TEXTURE MEASUREMENTS FOR QUALITY AND PRODUCTION CONTROL

Discussion of the applications of surface texture measurements to problems of quality control and its uses in the different processes of wood manufacturing including sawmilling, remanu-

Curtis Companies Inc. Becomes FPRS Supporting Member

Curtis Companies Incorporated returned to the ranks of FPRS 100 Company Supporting Members recently, and designated Lyle Sodeman, Director of Research and Development, as the company representative to the Society. Curtis has held memberships in FPRS almost since the latter's inception in 1947.

G. M. and C. F. Curtis first started the Curtis organization on the riverfront in Clinton, Iowa, in 1866. The local lumber supply was sufficient for their millwork business at first, but in 1881 a new factory was built at Wausau, Wisconsin. Later, warehouses were established throughout the country, and manufacturing facilities for special millwork items were added.

In 1919, Curtis Companies Incorporated was organized, and in 1937 all operating companies were absorbed into the parent organization and operated as divisions. Mr. G. M. Curtis, grandson of the original G. M. Curtis, is now Chairman of the Board, and in 1959, Mr. Perce C. Rowe, former president of Flintkote Co., was appointed president of Curtis. The company is in the process of changing to a jobber distribution policy, and is eliminating its warehouse system.

In the many years of its history, the business has been animated by a forward-looking, progressive spirit. Innovations have been numerous. Curtis was first to glaze windows at the factory and ship them in bundles, and first to make prefit sash. The Curtis SILENTITE window was the first radical improvement in the design and balancing of windows in several hundred years. The development of new products is under the direction of Lyle Sodeman, representative to FPRS.

In the present Curtis organization, entrance frames, doors, and window units are produced at the Clinton Iowa plant; flush doors and fixtures are made at the New London, Wisconsin, plant; and the Sioux City, Iowa, plant produces kitchen units.

EMPLOYMENT *Opportunities*

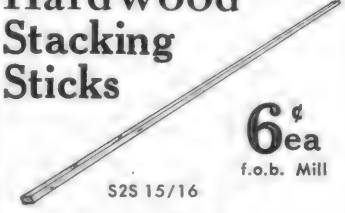
Employment Wanted

482—Plastics Eng. with wood eng. degree desires position in development work. 5 yrs. exp. in laminates, resin develop., paper impreg. and controls. Currently employed. (May)

519—June grad. MF in wood utilization desires teaching, research, or production management. Presently on staff of Eastern university. Age 25, married.

(Advertisement)

One Car 6-foot Hardwood Stacking Sticks



6¢ ea
f.o.b. Mill

S2S 15/16

GAIENNIE
Wholesale Lumber Co.
BOX 1774, SHREVEPORT, LA.

542—U. Minn. grad, Aug. '59, desires production, prod. dev., tech. sales, qual. control in midwest. B.S. in building products mchds. (May)

545—Grad. engr. 12 yrs. in production and sales of furn., cabinets, woodwork and plastic laminates desires product promotion and sales-service in woodworking or building. Extensive practical and education exp. S. W. or N. E. (May)

548—Grad. wood tech., 1957, seeks production trainee work in plywood, woodwork, etc. Has been in packaging industry. Midwest. (May)

549—Wood Tech., M.S., wants production or tech. sales and service. Exp. in production, qual. control, development, glues; also statistics, business and forestry. Midwest. (May)

485—U. Minn. grad, BS in wood tech. 7 years experience in gluing and laminating production and QC. Desires QC or development position in end and edge gluing. (June)

550—Industrial forester, utilization major, wants change with advancement possibilities. Exp. includes sales, administration, scaling, grading, tallying, etc. (June)

551—Iowa State grad, BS in wood tech. desires position in production, sales, or research. (June)

552—Wood tech MS desires research or production engineering. Background includes math, physics, statistics. (June)

554—Young exec. desires sales or production position, prefers Mid-Atlantic states. Exp. in wood parts includes research, product development, manufacturing, sales, administration. (June)

Positions Offered

E–347—Operations Mgr. for midwest furniture plant. Wood tech. plus several years supervisory exp. Responsible for all operations except sales, finance, design. Ideal living conditions; expansion possibilities. (May)

E–350—Log and timber buyer, Ohio. National, multi-mill concern. Age under 45 with woods and mill know-how. Advancement possibilities. (May)

E–351—Ass't. Supt. for Hamilton Mfg. Co., Two Rivers, Wis. Young man with furn. exp. in highly mechanized plant. Will supervise 200 employes in plywood layup, assembly, finishing of lab. and school furn. New plant under construction. Age, under 40. Write Personnel Mgr. (May)

WANTED MANAGER

Wood technologist with practical experience in production to manage modern wood working plant in East Tennessee. Applicant must have had several years practical experience in the direction of production and he must be able to assume responsibility so as to take complete charge of the operation. Because plant is highly mechanized, the ability to see that equipment is properly maintained is important. Salary and bonus in high four figure bracket. This is a good opportunity for a competent person.

Send replies to:

E-340, Employment Service
FOREST PRODUCTS RESEARCH SOCIETY
417 North Walnut Street
Madison 5, Wisconsin

Fig. 4.—Movable upper half of the vessel in the closed position with the millwork immersed in preservative.

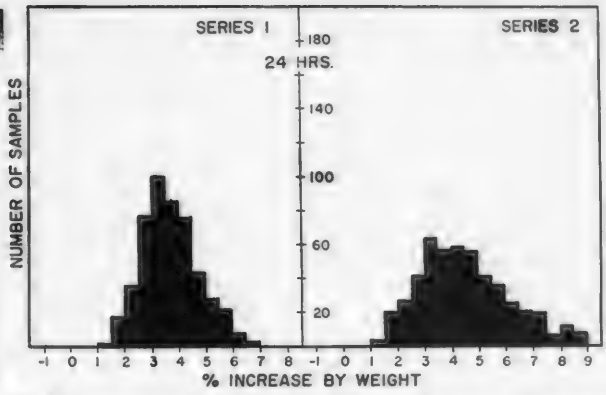


Fig. 8.—Absorption of solution after 24 hours by Series 1 (3-minute dip) and Series 2 (vacuum process) samples.

Findings of Final Evaluation

In spite of the careful selection of samples, a number of pieces of "sinker-stock" appeared in the group. Of particular interest was the fact that the samples with excessive absorption in load I did not necessarily correspond with those in load II, which indicates that the "sinker-stock" effect is purely a local condition. The statistics on per cent by weight absorption were presented in two sets, one being all samples in each series. The other, entitled "selected", had abnormal percentages eliminated before the averages were calculated.

Ten samples in series I that had increases at the end of 24 hours of 8 per cent or greater were eliminated for the selected group; 13 samples in series II that had increases at the end of 24 hours of 9 per cent or greater, were eliminated.

A comparison of series I with series II at the end of 24 hours is shown in Fig. 8. Here the height of the bars indicates the number of samples by each one-half per cent.

Fig. 9 shows the results after seven days, and Fig. 10 shows the per cent increase by weight after 30 days. The apparent over-treatment is demonstrated by the data in Table 2, which show the per cent increase in treatment by the vacuum system, as compared with the 3-minute dip, at each weighing period.

The deeper penetration, and consequently slower drying, of the vacuum treatment is definitely proven by the 30-day figures as compared with the two previous weighings. The per cent over-treatment increases and then decreases with time. This indicates that, originally, approximately the same amount of solution is picked up by the wood with either process, but due to the deeper and more thorough treatment by the vacuum method, the solvent requires a much longer period of time in which to volatilize.

The reduction in degree of over-treatment of "sinker-stock" when the vacuum method is used is apparent when the net increases in per cent by weight of these samples are studied. As shown in Fig. 11, samples subjected to the 3-minute dip had up to 60 per cent increase by weight. Fig. 12 shows that the majority of the "sinker-stock" samples in the vacuum series had about 10 per cent increase, with a high of 30 per cent. Figs. 11 and 12 also show that the loss on drying was greater with the series subjected to the vacuum treatment. It is felt that this is due, once again, to the type of deep, even distribution of the penta with the vacuum procedure. Also, as is obvious, the material that goes into the wood more easily, will come back out more readily when the drying vacuum is applied.

Since volumes, weights, and per cent increases by weight for 1,000 samples were already tabulated, it was advantageous to plot specific gravity versus per cent retention and determine the range of specific gravities encountered. Fig. 13 clearly demonstrates the complete lack of any relationship between specific gravity and the per cent retention.

Fig. 14 shows the range of specific gravities encountered, and the frequencies. It should be noted, however, that these figures pertain to a select set of sapwood samples.

Subsequent to the above determinations, samples were cut from the end of the 1,000 used and subjected to the chlorine-peroxide (or Sanderman–Jonas) quantitative test to permit a visual examination of end and side penetration. This gave an ultimate verification of the retention figures, and definitely correlated the results of the 3-minute dip with the vacuum proce-

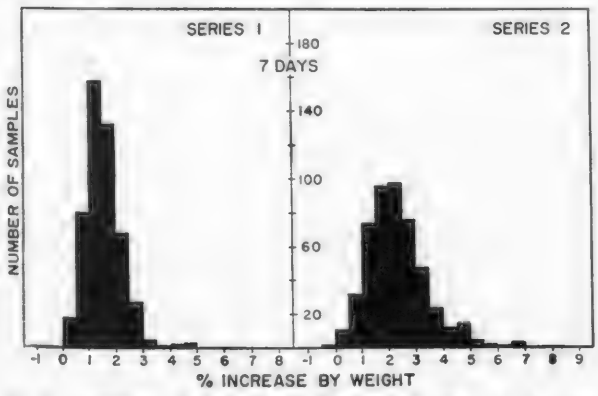


Fig. 9.—Absorption of solution after 7 days by Series 1 (3-minute dip Series 2 (vacuum process) samples.

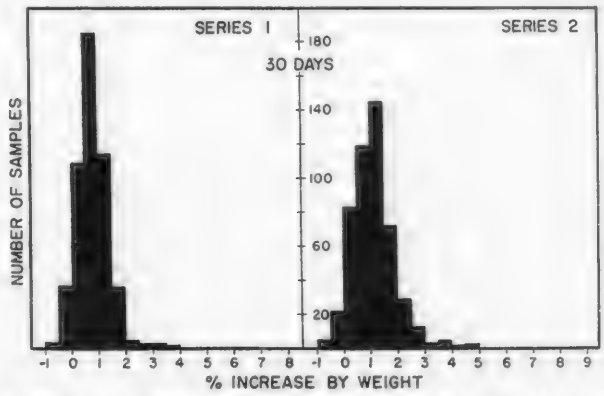


Fig. 10.—Absorption of solution after 30 days by Series 1 (3-minute dip) and Series 2 (vacuum process) samples.

Table 1.—COMPARISON OF VACUUM AND 3-MINUTE DIP TREATMENTS

Method of treatment	% Penta—Sides			% Penta—Ends		
	1st ½	2nd ½	3rd ½	1st Inch	2nd Inch	3rd Inch
Vacuum	0.697	0.376	0.219	0.595	0.152	0.083
3-minute dip	.521	.241	.153	.444	.124	.048
% difference	33.6	56.0	43.0	33.5	22.5	73.0

Table 2.—PER CENT INCREASE IN TREATMENT BY VACUUM TREATMENT, AS COMPARED WITH 3-MINUTE DIP

	24 hours	7 days	30 days
Unselected	13.77	27.13	7.48
Selected	20.27	45.51	36.25

dure. This verification was sufficient to certify that all the requirements had been met for the NWMA license.

Relative Extent of the Penetration Evaluation

Because the results from the chlorine-peroxide evaluation did not lend themselves to an accurate measurement, it was decided to set up another test series to demonstrate end-penetration only. There was also some question about some samples ending up with a negative increase in weight after 30 days of drying. Since test conditions were standard and the entire question of retention by weight was purely relative, these negative values did not nullify the program. The change of emc during the test period was questioned, however.

A selected piece of ponderosa pine cut stock was divided in six equal pieces, 2 by 2 by 10 inches. These pieces, after being labeled, were stored in an exposed condition in the laboratory for 45 days, and were weighed every week day. This procedure resulted in the stabilization of the wood to an emc compatible with the laboratory conditions. It also provided a graph that showed the weight loss during the period of exposure. In addition, the processed samples would show weight losses due only to evaporation of the solvent.

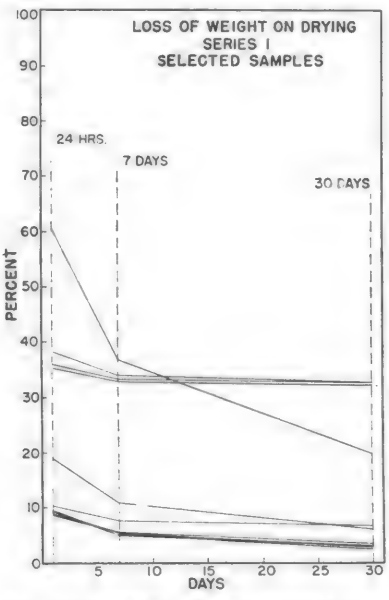


Fig. 11.—Selected samples subjected to a 3-minute dip.

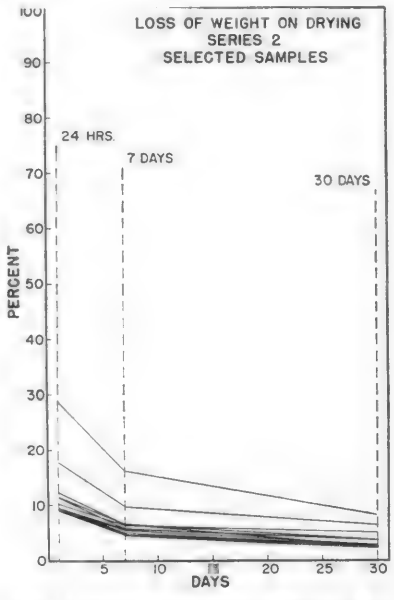


Fig. 12.—Selected samples subjected to the vacuum process.

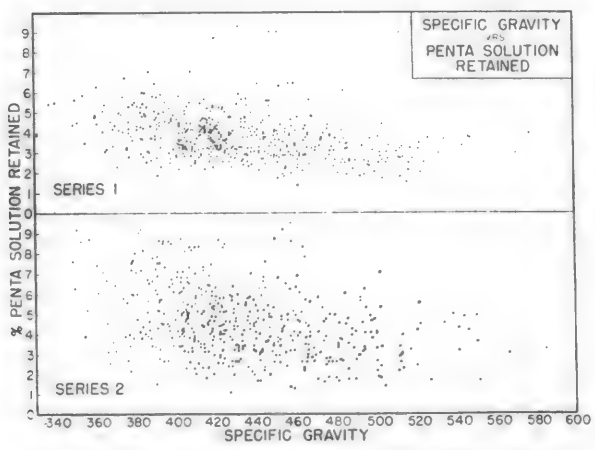


Fig. 13.—Per cent penta solution retained plotted against specific gravity.

Two of the six pieces were left untreated as controls, two were run through the vacuum procedure, and two were treated by the 3-minute dip. Daily weighings were then made, recorded, and graphed over a period of 45 days. The result of the determination of retention by per cent increase in weight verified for the third time the findings that the vacuum procedure cycle provided retention equal to or greater than the 3-minute dip.

Each of the samples was then cut lengthwise so as to produce four 10-inch sticks, ⅝ by ⅝ inch, thereby leaving a cross-shaped section 10 inches long. Eight exposed faces were thus produced on the cross-shaped section. Each stick and face was identified as to location, and all pieces were subjected to the chlorine-peroxide test to determine the depth of end and side penetration. These were then measured for both the extent of complete penetration and also the maximum point reached by any amount of penta. A study of these results clearly established the average of 1½ inch end pentration, for both the 3-minute dip and the vacuum procedure. The use of blank controls throughout this test verified that the results obtained were due only to the penta.

Average end penetrations of up to 5¾ inches and as small as ½ inch were obtained, with the over-all average end penetration by the vacuum procedure being slightly greater than that obtained by the 3-minute dip. The more even dispersion of penta throughout the treated area of the vacuum samples was very apparent in the dyed sticks, with the difference between areas completely penetrated and the extreme extent of any penetration being considerably less than with the 3-minute dip samples.

After all these tests were completed and evaluated, the figures on the original 1,000 samples were restudied. Each set of 500 was re-evaluated by the 100's. Although the results by lots of 100 checked out fairly close, it was

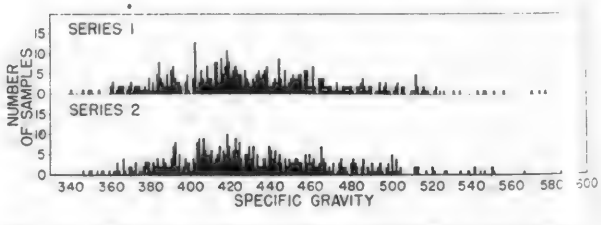


Fig. 14.—Range of specific gravities encountered in the program.

obvious that 500 samples give a more accurate determination of the relative retention on a per cent increase by weight basis.

On a 30-day basis, 500 samples, the costs indicated an over-teratment of 7.48 per cent. When "sinker-stock" samples were eliminated (for, as shown previously, "sinker-stock" is excessively over-treated in the 3-minute dip), the over-treatment of selected samples in the vacuum system was found to be 35.25 per cent. One might be led to conclude that this is economically unjustifiable, but the true figure to study from the standpoint of solution usage is the 7.48 per cent. Because less penta is left in "sinker-stock" as a result of the vacuum procedure, the normal wood items can be considerably overtreated without an excessive increase in the amount of solution used. In other words, it is all there, but with better distribution.

The laboratory facilities and trained technicians were available for running lime-ignition analyses, so a program was set up to determine whether the vacuum process affected the penta content of the solution in the tank, through loss by evaporation, vacuum withdrawal of solvent with an abnormal penta residue being left behind, or any other unpredictable factor. Periodic quantitative analyses of the tank solution showed no noticeable change in the penta content as a result of production operation.

Summary

The vacuum procedure for the water-repellent preservative treatment of ponderosa pine millwork has been successful for CARADCO. The process provides: 1) a greater output per day with less labor, 2) a cleaner and safer work area, 3) a drier product with less delay before the glazing or priming operation, and 4) improved working conditions in and around the area. It also reduces over-treatment of "sinker-stock", and improves the distribution of penta throughout the treated area. Finally, the penetration and retention conform to NWMA requirements.

Additional findings that resulted from the study were that: 1) the incidence of "sinker-stock" was on the order of two to three per cent of the samples, 2) "sinker-stock" appears as a localized condition, and matched samples do not conform in this respect, 3) there is no relationship between specific gravity and retention, 4) the specific gravity of sapwood samples varies over a relatively wide range, and 5) the penta content of solutions in tanks remains quite constant during daily usage.

A TECHNICAL REVIEW OF DEVELOPMENTS IN

Microbiological Utilization of Wood Sugars[1]

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Economic use of wood residues awaits use developments for each of the 3 major components. Wood sugars in acid hydrolyzates and spent sulfite liquor are a potential source of many chemicals. Only ethyl alcohol and yeast are now produced commercially.

WHAT THIS RESEARCH MEANS

The wood waste residues produced annually in the United States represent a tremendous amount of carbohydrate material that is at present not being utilized. Similarly, spent sulfite liquor is another source of little-used carbohydrate. The development of economically sound methods of utilizing wood residues is important not only in dealing with these wastes, but also in forest management. For example, if profitable uses can be found for wood residues, culls, and inferior species, then the clearing of forest lands of undesirable species, reforestation, and fire control might be put on a self-sustaining basis.

Ethyl alcohol and fodder yeast are now being produced commercially from spent sulfite liquor, and on the basis of what we already know, many more chemical compounds can be produced by microbiological means from wood sugars. These sugars can be isolated from either spent sulfite liquor or the acid hydrolyzates of wood residues.

For further microbiological utilization of wood residues to be economical, profitable uses must also be found for the two other major components of wood, lignin and hemicellulose.

Editor

DURING THE PAST SEVERAL YEARS the Forest Products Laboratory has conducted research on the utilization of wood residues by chemical and microbiological means. In this work, residues with structural or fiber properties were excluded, since processes for utilizing material with these characteristics are being used commercially.

The wood residue problem is a tremendous one. In the United States alone, somewhat more than 4.8 billion cubic feet, or approximately 75 million tons of plant and logging residues are produced annually (27).[3] Of this, about 44 per cent is used for fuel and the rest finds no use at all. Wood contains from 40 to 55 per cent cellulose, 15 to 25 per cent hemicellulose, 15 to 30 per cent lignin, and from 2 to 15 per cent extraneous and extractive material.

Thus in the 75 million tons of plant and logging waste, there are upwards of 40 million tons of carbohydrate material. Since the annual world production of raw sugar for the years 1950 to 1955 amounted to 36 to 42 million tons (26), it can be readily appreciated that wood is potentially one of the most important and widespread sources of carbohydrates.

Economic utilization of these vast quantities of carbohydrates and lignin

[1] Presented by title at Session XIII, Chemical Utilization, FPRS 12th National Meeting, June 22–27, 1958, Madison, Wis.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to the Literature Cited at the end of this report.

The Author: George Hajny received a BA degree from Colgate University, and a PhD in chemistry from the University of Wisconsin while at the FPL, where he has been since 1942.

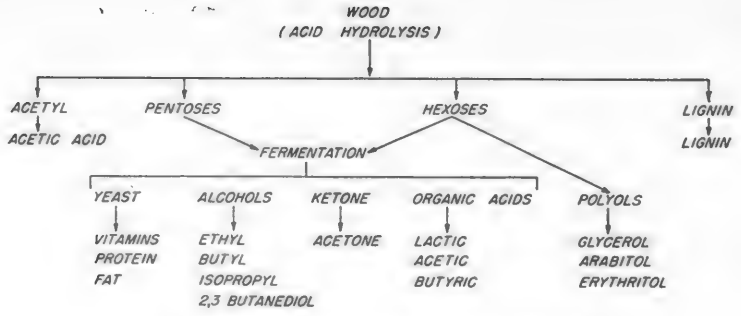

Fig. 1.—Fermentation products of wood hydrolyzates.

would not only solve the problem of disposal of these wastes, but might ultimately result in an important tool in forest management. For example, forest lands in which cull trees and unused species predominate might profitably be cleared and planted to trees of greater value.

Historically, utilization of wood residues by chemical and microbiological means has been developed to produce one product, ethyl alcohol, which in most cases has not been able to bear the cost of the process. Present thinking at the Forest Products Laboratory is aimed at total utilization of the three largest components of wood. Rational utilization of each fraction demands that it be separated and fractionated from the other components in as mild a manner as possible. Each fraction can then be processed under optimum conditions for that particular fraction.

Lignin is the Key

As an example, the wood residue might first be treated to remove the lignin and hemicellulose by hydrotropic solvents. (It is conceivable that a type of lignin would be obtained that has commercial possibilities.) Along with the lignin, a pentose-rich carbohydrate fraction would be obtained that could be further treated to yield furfural. The final fraction of the wood residue would contain the original cellulose in the wood, and on further hydrolysis would yield glucose, from which a number of products could be made, depending on the final processing.

The key to successful utilization is the lignin. If processing results in a novel type of lignin, the outlook for successful wood residue utilization would be bright, since each major component of the wood would bear its share of raw material and processing costs.

Most methods for the microbiological utilization of wood have used, as the starting material, wood sugars produced by the acid hydrolysis of wood residues or the sugars present in spent sulfite liquor. Attempts have been made to ferment wood directly. Thus, Virtanen and others (28, 29), using finely ground sawdust as a substrate, found that a culture of thermophilic cellulose bacteria would ferment up to 68 per cent of the cellulose in the sawdust in 3 to 4 weeks.

Work carried on at the U. S. Forest Products Laboratory (6) with the thermophilic cellulose bacteria showed that this culture could utilize all the simple sugars commonly found in wood, as well as holocellulose, hemicellulose, and alpha cellulose. The products of this fermentation are acetic, butyric, and lactic acids in yields of about 50 per cent of the carbohydrate consumed. When wood in the form of sawdust rather than the isolated carbohydrates is used as a substrate in this fermentation, the products obtained are the same, but the time of fermentation is greatly increased and the fermentation stops long before all the carbohydrate in the wood is utilized. For example, after 14 days' fermentation, sweetgum sawdust produced yields of mixed acids equal to 15.9 per cent of the dry weight of the wood. The extreme resistance of wood to bacterial action is thought to be caused by the close association between the cellulose and lignin in the wood (18).

Fig. 1 is a schematic representation of the products formed from wood by acid hydrolysis, and the products that have been obtained by fermentation of the pentoses and hexoses. Wood sugar solutions have generally been used as prepared, with no attempt to separate the hexoses from the pentoses. Many bacteria can utilize both hexoses and pentoses. On the other hand, while yeasts can use only hexoses in anaerobic fermentations, some yeasts can utilize pentoses in aerobic fermentations.

Ethyl Alcohol Fermentation

The priamry goal of most wood saccharification processes has been to obtain a sugar source for the production of ethyl alcohol by fermentation. The sugar solution obtained in the saccharification process is not an ideal one for this purpose. The solution is relatively dilute, and contains only from 5 to 6 per cent of reducing sugars. Furthermore, a mixture of hexose and pentose sugars is obtained, some of which are not fermentable to ethyl alcohol. Thus, the total hydrolyzates of softwoods are 77 to 88 per cent fermentable, while similar hydrolyzates from hardwoods are 65 to 75 per cent fermentable. These hydrolyzates are difficult to ferment by conventional methods. Leonard and Hajny (13) list four potential sources of toxicity in wood hydrolyzates: 1) breakdown products of sugars, 2) soluble lignin products, 3) wood extractives, and 4) heavy metal ions from equipment corrosion. Toxicity from items 3 and 4 can be controlled to a large extent by choice of wood species and by proper selection of hydrolysis equipment.

Many treatments have been found to be of use in preparing a hydrolyzate that is relatively easy to ferment. Among the treatments used are 1) steam distillation (13); 2) use of large inocula; 3) acclimatization of the organisms (10, 12); 4) liming to pH 9, filtering, and readjusting the pH; 5) addition of small quantities (0.2 per cent by weight of sugar present) of sulfur dioxide to lower the oxidation-reduction potential (13); 6) use of activated charcoal; and 7) ion-exchange and ion-exclusion methods.

With a sugar concentration of 5 per cent, which is about the strength of sugar solutions obtained from the hydrolyzer, no pretreatment of the liquor is necessary for alcoholic fermentations if a preformed inoculum is used. However, for some fermentations—for example, glycerol—sugar concentrations of 20 per cent may be desired. In such cases, pretreatment of the liquor is necessary, for even large inocula cannot function properly. Fig. 2 shows rate of fermentation curves for untreated and treated 20 per cent wood-sugar solutions, as compared with a glucose solution of similar concentration.

Techniques used in grain or molasses fermentations do not work when applied to wood-sugar fermentations. Thus in a molasses fermentation, a ten- to twentyfold increase in cells occurs during the fermentation, while under similar conditions, wood-sugar fermentations yield only a two- to fourfold increase. In order to obtain a reasonable rate of fermentation, a preformed inoculum is necessary.

Harris and coworkers (7) used the following method for fermenting Douglas-fir wood-sugar hydrolyzates containing about 5 per cent of reducing sugars. The acid hydrolyzate was

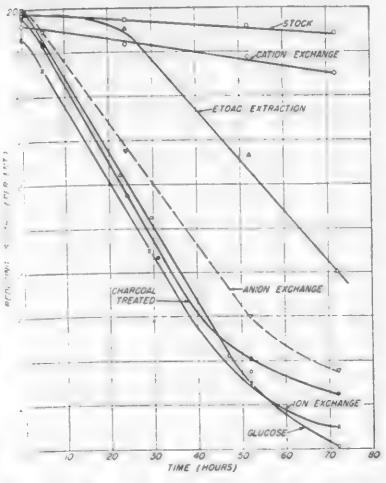

Fig. 2.—Rate of fermentation for treated and untreated wood–sugar solutions.

first neutralized to pH 3.5 to 4.0 with lime, and the precipitated calcium sulfate was filtered off. The pH was then adjusted to 5.6 to 5.8 with sodium hydroxide. Nutrients were added in the form of urea at a 0.01 per cent concentration and sodium or potassium phosphate at a 0.003 per cent concentration. Sufficient inoculum was then added to give a 1 per cent yeast volume. This amonut of yeast was sufficient to complete the fermentation in 18 to 20 hours. Upon completion of the fermentation, the yeast was centrifuged from the beer and a new fermentation was started with the recovered yeast. Forty-nine fermentations were carried out, the yeast being recycled each time with no apparent weakening of its activity. Although the fermentations were not run under aseptic conditions, no evidence of gross contamination was observed. For 49 fermentations, the Douglas-fir hydrolyzates had an average fermentability of 83.5 per cent, and alcohol yields were 39.3 per cent of the total reducing sugars or 47.2 per cent of the fermentable sugars. These authors (10) also developed a continuous alcoholic fermentation in which yeast was recycled. Alcohol yield was almost identical to that obtained in batch fermentations.

Johnson and Harris (12) investigated 20 different strains of yeast for their ability to grow and to produce alcohol from wood sugars. In this work, an initial inoculum of 1 per cent of yeast by volume was used, and fermentations were made daily by centrifuging and transferring the yeast. Some of the yeasts made poor growth or produced little alcohol in the first few transfers. By the twelfth transfer, however, all the strains were utilizing the fermentable sugar and producing good yields of alcohol. This work showed clearly that, with certain strains of yeast, acclimatization to the wood-sugar solutions is very important.

Spent sulfite liquor contains the same sugars obtained from wood by acid hydrolysis. Spent sulfite liquor cannot be fermented directly because of the presence of free sulfur dioxide or sulfurous acid. Two methods used to remove the sulfur dioxide are steam stripping and precipitation with lime. Although sulfite alcohol has been produced by many mills in Europe for many years, there are only three mills on the North American continent, and all were started comparatively recently. These mills have been described in the literature (2,3,4,23,30). In the three American mills, the yeast is recovered and recycled through the process. Yields of alcohol vary somewhat because of differences in pulping and washing, but 20 gallons of 95 per cent alcohol can be obtained per ton of pulp.

In the production of alcohol by yeasts, only the hexose sugars are utilized for the production of alcohol. Some work (13) has been done with *Fusarium lini,* which can produce ethyl alcohol from both hexoses and pentoses. Although all the sugars in the wood hydrolyzate were utilized and a 45 per cent conversion to alcohol was obtained, the process did not appear promising, since seven days were required to ferment a five per cent sugar solution.

Butanol Fermentation

The butanol fermentation is well suited for use on wood hydrolyzates, since the organism *Clostridium butylicum* used by most workers (24,15,32) can convert pentose as well as hexose sugars. Pretreatment of the hydrolyzate is necessary before easily fermentable solutions are obtained. Furfural appears to be the principal toxic compound. Leonard and others (15) showed that wood species as well as method of hydrolysis affects the fermentability of solutions. Pretreatments of the hydrolyzate solutions involve steam distillation, or liming to pH 10, and filtration. When adequate pretreating methods are used, fermentabilities of 85 to 94 per cent are obtained. Yields of neutral solvents, butanol, ethyl alcohol, and acetone or isopropyl alcohol are in the range of 30 to 35 per cent of the fermentable sugars. The neutral solvents are obtained in approximately the following proportions: 60 per cent of butanol, 10 per cent of ethyl alcohol, and 30 per cent of acetone or isopropyl alcohol.

Wiley and coworkers (32) studied the same fermentation, using spent sulfite liquor as a substrate. It was found necessary to pretreat the liquor with lime up to pH 12.5 in order to precipitate sulfite and lignin complex before good fermentations could be obtained. Some 70 to 80 per cent of the reducing substances were utilized in the fermentation, and yields of neutral solvents were about 26 per cent. It was found that this method of pretreatment and fermentation reduced B.O.D. values to 19.3 per cent of the original value.

Lactic Acid Fermentation

Marten and associates (16) were interested in fermenting the sugars remaining in the still residues from the ethyl alcohol fermentation of wood sugars produced by the one-stage American process for hydrolyzing wood. They found that their organism, *Lactobacillus pentosus* 124–2, would utilize 75 per cent of the reducing substances in the still residue. In work on pure sugars, they showed that this organism would produce lactic acid with only a small amount of acetic acid from glucose; but when xylose was used, 1 mol of lactic acid and 1 mol of acetic acid were produced from each mol of the pentose.

The same organism was used by Allgeier and coworkers (1) on the total wood hydrolyzate. With sugar concentrations of 7 to 10 per cent, 82 to 88 per cent of the sugars were utilized. Yield of total acid produced amounted to about 95 per cent of the sugar used. Approximately 95 per cent was lactic acid and 5 per cent acetic acid.

The production of lactic acid from spent sulfite liquor was reported on by Leonard and coworkers (14). Pretreatment of the liquor was necessary to obtain good fermentation. The method used consisted of steam stripping the sulfur dioxide, raising the pH to 8.5 with calcium hydroxide, filtering, and adjusting the pH to 6. Yields of combined acids amounted to 95 per cent of the sugar used. The authors estimated that, for each ton of pulp produced, 300 pounds of lactic acid and 80 pounds of acetic acid could be produced from the spent liquor.

2, 3 Butanediol Fermentation

The production of 2, 3 butanediol from both hardwood and softwood hydrolyzates has been investigated by Perlman (19). A culture of *Aerobacter aerogenes* was used. This organism was able to convert both pentose and hexose sugars, utilizing up to 94 per cent of the reducing sugars in a red oak hydrolzate.

Two methods of pretreating the hydrolzate were used. In the first, the

pH of the hydrolyzate was raised to 6 with lime and the precipitated calcium sulfate was filtered off. In the second, the pH was raised to 10 or 11 with lime and the hydrolyzate then filtered, after which its pH was adjusted to 6. With low concentrations of sugar in the hydrolyzate, both methods of pretreatment gave good results on fermentation. However, with high concentrations of sugar fermentations were difficult with the first method of pretreatment unless supplements of malt sprouts or yeast extract were added to the medium. It was further found that the simple pretreatment was satisfactory with the higher sugar concentrations if the organism had been acclimatized to the wood hydrolyzates. Wood-sugar solutions of up to 18 per cent concentration were fermented satisfactorily with yields of butanediol of about 35 per cent, based on the sugar utilized.

Glycerol Fermentation

Recently the U. S. Forest Products Laboratory has been engaged in an investigation of the production of glycerol, both by hydrogenolysis and by fermentation of wood sugars.

It has been known since the time of Pasteur that glycerol is normally produced in alcoholic fermentations in amounts of 2 to 3 per cent of the sugar. Neuberg (17) showed that glycerol is the main product of the fermentation if the acetaldehyde produced is trapped by sodium bisulfite. He suggested the following equation for a fermentation of this type:

$$C_6H_{12}O_6 + NaHSO_3 = CH_3CHO \cdot NaHSO_3 + C_3H_8O_3 + CO_2$$

Inspection of this equation reveals that in the beer produced there is one mol of sodium bisulfite for every mol of glycerol. This large amount of soluble salt in the fermented beer makes glycerol recovery extremely difficult. It has been the main stumbling block to the successful exploitation of fermentation glycerol. Newer techniques of purification and recovery, including ion exclusion and ion exchange, have been developed since much of the work on the glycerol recovery was done. Work on glycerol recovery, by means of ion exclusion and ion exchange, is now going on at the U. S. Forest Products Laboratory. Although all of the details of the recovery have not as yet been solved, the process looks very promising.

Because the recovery of glycerol is difficult, glycerol concentration in the beer should be as high as possible. In order to secure this, sugar solutions of 20 per cent concentration have been used. As seen from Fig. 2, this necessitates a purification pretreatment of the wood-sugar hydrolyzate. Ion exchange has been chosen as the method of purification.

Sodium bisulfite, the steering agent used in the glycerol fermentation, is somewhat toxic (5). Thus, its concentration in the medium must be carefully controlled. All the sodium bisulfite needed cannot be added at the start of the fermentation, so it must be added throughout the fermentation. Limitations are also imposed on the pH of the medium, since at low pH levels the sodium bisulfite is highly toxic because of increased concentration of the bisulfite ion, while at higher pH levels increased amounts of salts would have to be dealt with in the recovery process.

Batch fermentations were made with wood-sugar hydrolyzates, and fermentation conditions were determined. A continuous glycerol fermentation was then developed. A brief description of the continuous process as finally developed is as follows:

Two stainless steel fermentors connected in series are used. The fermentors are equipped with level and temperature controls. A 20 per cent sugar feed is metered to the first fermentor. At the same time, a yeast cream containing added nutrients, a sodium bisulfite solution, and a sodium carbonate solution are each metered separately to the fermentor. The feed rates are so chosen that a yeast level of about 3 per cent cell volume is maintained in the fermentation. The sodium bisulfite solution is fed at such a rate that a concentration of 0.7 to 1.0 per cent of free sodium bisulfite is maintained in the first fermentor. The sodium carbonate solution is fed at such a rate that a pH of 6.5 is maintained in the fermenting medium. The temperature is held at 30° to 32° C. Once the fermentation has stabilized, very little adjustment of feed rates is necessary to maintain desired conditions in the fermentors. From the second fermentor, the fermentation liquor flows to a holding tank. The yeast is removed from the beer by centrifuging, and is recycled in the process.

The fermentation is not run under aseptic conditions. The yeast obtained from the centrifuge, however, is given an acid wash at pH 2.5 for one hour, which quite effectively controls contamination by bacteria. After the acid wash, nutrients are added to the yeast cream. The nutrients are as follows in per cent by weight of the medium: urea, 0.075 per cent; disodium phosphate, 0.048 per cent; potassium chloride, 0.016 per cent; magnesium sulfate, 0.004 per cent; and blackstrap molasses, 0.25 per cent. Although yeast reproduction is very poor in a sodium bisulfite solution, an increase in yeast of 10 per cent per day was noted during several months' fermentation.

Under the fermentation conditions described, the throughput, or fermentation, time was 60 hours. With higher yeast volumes in the system, the second fermentor could be dispensed with and fermentations could be completed in 36 hours. Fermentations have been run for several months at a time with no indication that the yeast was losing its effectiveness. Yields of glycerol amount to 28 to 30 per cent; ethyl alcohol, 0 to 22 per cent; and acetaldehyde, 2 to 14 per cent based on total sugar fed to the system.

Arabitol and Erythritol Fermentation

While the pilot plant work on the bisulfite glycerol fermentation was continuing, bench-scale studies were being made of the production of glycerol, arabitol, and erythritol by yeasts of the genus *Zygosaccharomyces*. Spencer and associates (25) had shown that, in a medium of yeast extract and with aeration, increased yields of polyhydric alcohols were obtained. No steering agent, such as sodium bisulfite, was required in these fermentations.

At the Forest Products Laboratory, classified cultures (20) and isolates were screened in a search for cultures that would produce glycerol as the only polyhydric product. As a result of this screening program, three cultures were chosen for further study. One produced only glycerol; the second, only arabitol; and the third, erythritol with only traces of arabitol. Most of the cultures screened produced arabitol with varying quantities of glycerol.

Of the sugar in wood hydrolyzates, these cultures readily utilize glucose and mannose. Xylose, arabinose, and galactose are metabolized very slowly and, although yeast growth occurs, no polyhydric alcohols are produced. With the culture producing glycerol, yields of 35 per cent of glycerol are obtained. Over 50 per cent of arabitol can be obtained with the second isolate. The third culture will produce erythritol in yields of about 22 per cent. Total polyol production for several of the classified *Zygosaccharomyces* (20) approached 75 per cent of the sugar used.

Yeast Propagation

Fermentation of sugars for yeast production is a method whereby carbohydrates and inorganic salts may be converted to protein, vitamins, and fats. The dry yeast contains about 50 per cent of protein and 3 to 7 per cent

f fat, and is produced in yields of 45 50 per cent of the sugar consumed. he yeast most commonly used for dder yeast is *Torulopsis utilis*. Since propagation this culture uses pen- se as well as hexose sugars it is well suited for use on wood hydrolyzates d spent sulfite liquor.

Much of the pioneering work on this fermentation was done in Germany before and during World War II. Zellstofffabrik Waldhof developed a fermentor that was highly successful. The fermentor is essentially an open tank provided with a center draft tube. Air is introduced to the fermentor by means of an aeration wheel located beneath the draft tube. In the Waldhof plants, a hollow driveshaft for the aeration wheel served to supply air to tubes on the top surface of the aeration disk. The air tubes led to the periphery of the disk, where the air was dispersed in the liquid. The aeration wheel also served as an agitator, and pumped the emulsion down the draft tube and up between the fermentor wall and the draft tube. Good descriptions of the German plants may be found in the report by Saeman, Locke, and Dickerman (22); of the Lake States Yeast Corp. plant in reports by Wiley and coworkers (31) and Holderby (11); and of a pilot-plant fermentor in a report by Saeman (21).

One of the outstanding features of the Waldhof fermentor is the fact that the excessive foaming caused by wood sugars when used in other types of aerated fermentors is mechanically controlled. Under equilibrium conditions, the contents of the fermentor are in the form of an emulsion with a specific gravity of 0.4 to 0.45.

The second important feature of the Waldhof fermentor is the fact that it is continuous. Sugar and nutrient salts are fed continuously, and beer and yeast are removed continuously. The through put time of a 2 to 5 per cent sugar solution is 4 to 4.5 hours. Although aseptic conditions were not maintained, fermentations with wood-sugar hydrolyzates have been run for months with no evidence of gross contamination.

Harris (9) has determined the amount of nutrients consisting of nitrogen, phosphorous, potassium, and magnesium necessary for yeast production. Nitrogen may be supplied as urea, ammonia, or ammonium salts. For 100 pounds of sugar, 3.2 to 3.6 pounds of nitrogen, 1.5 pounds of P_2O_5, and 1.5 pounds of potassium sulfate are required. Addition of magnesium salts had little effect. Two hundred cubic feet of air were required per pound of dry yeast produced.

Wiley and coworkers (31) have determined the vitamin and amino acid content of Torula yeast. In general, yeasts are a rich source of the vitamins of the B-complex. Torula yeasts compare favorably with brewer's yeast in all the B vitamins, with the exception of thiamin in which Torula is rather poor. About one-half the weight of dry Torula yeast is protein. In amino acid composition this protein compares quite favorably with casein. Harris and coworkers (8), in rat-feeding tests, compared the protein of Torula yeast and casein. It was found that the protein of Torula yeast was low in the amino acid methionine. If the Torula protein was supplemented with methionine, growth of rats on casein and the supplemented Torula protein was comparable.

Conclusion

A variety of chemical compounds can be produced from the wood sugars in spent sulfite liquor or in acid hydrolyzates of wood. At the present time, only ethyl alcohol and yeast are being produced commercially from spent sulfite liquor. These processes are being used primarily to alleviate stream pollution. Economic utilization of wood residues through acid hydrolysis awaits developments based on uses for each of the major components of wood.

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Chemical Conversion of Wood Residues, Part II:

Kinetics of the Acid-Catalyzed Conversion of Xylose to Furfural[1]

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Furfural yields from xylose increase with increasing temperature and decreasing xylose concentrations. The acid concentration has no effect on yield when above 0.1N H_2SO_4. Results indicate that favorable yields of furfural can be obtained when xylose is processed in dilute solution at high temperature in a simple, single-pass reactor without continuous removal of furfural.

When aqueous acidified xylose is heated, the furfural concentration follows a characteristic growth and decay curve. Two rate phenomena that are associated with the rate of furfural formation are readily observed in separate experiments. These phenomena are the disappearance of xylose in aqueous acid, and the disappearance of furfural under the same conditions of temperature and acid concentration at which it is formed.

Several investigators (7, 11, 15)[3] have shown that xylose undergoes a first-order disappearance when it is reacted with aqueous sulfuric acid; rates have been measured over ranges of temperature of 100° to 200° C. and sulfuric acid concentrations of 0.5 to 16 per cent. The energy of activation is about 32,000 calories per gram-mole, and the reaction rate constant k_1 is nearly directly proportional to acid concentration.

Williams and Dunlop (14) found similar behavior with furfural. When acidified aqueous furfural is reacted isothermally, it undergoes first-order decomposition and forms a dark, resin-like substance. Their tests covered the ranges of 150° to 210° C. and 0.05 to 0.1 N sulfuric acid. An energy of activation of 21,970 calories per gram-mole was reported, and the reaction rate constant k_2 was directly proportional to acid concentration.

If only these two rate phenomena determined the rate of furfural formation, the reaction mechanism would be as follows:

$$\text{Xylose} \xrightarrow{k_1} \text{furfural} \xrightarrow{k_2} \text{destruction products}$$

Since k_2 is much smaller than k_1 in the range of conditions given above, high yields of furfural would be expected. The literature contains few data on the rate of furfural formation, when pure xylose is used as the source material. However, it has been found that, regardless of the source material, furfural yields are much lower than those predicted by the simple two-step mechanism. Wilson (15) measured the furfural yields from pure xylose at 180° C. in 0.08 per cent sulfuric acid and found a maximum of about 50 per cent (of theoretical yield) at 4 hours. With the values of k_1 and k_2 Wilson obtained in separate experiments, the two-step mechanism predicts a maximum yield of 83 per cent.

Observed low yields clearly indicate a yield-reducing side reaction. Since quantitative yields were obtained by Pervier and Gortner (10) and Hughes and Acree (4) by rapid removal of the furfural from the solution with steam, the side reaction must be an interaction between furfural and a furfural precursor. Dunlop and Peters (2) observed that the quantity of furfural present did not affect the rate of xylose disappearance, and concluded that, if there is an interaction, the precursor is not xylose but one or more of the intermediate products that result from the conversion of xylose to furfural. Such intermediates have been suggested by Hurd and Isenhour (5) and Wolfrom, Schuetz, and Cavalieri (16), although there is yet no evidence that any of these have been isolated.

On the basis of these observations, Dunlop (1) proposes the following mechanism for the reaction:

$$\text{Xylose} \xrightarrow{k_1} \text{(intermediates)} \longrightarrow \text{furfural} \xrightarrow{k_2} \text{destruction products}$$

$$\text{(intermediates)} \rightleftarrows \text{condensation products}$$

Purpose and Scope of Investigation

The purpose of this research was to determine reaction rates and yields experimentally and to develop a mathematical correlation to describe the results.

On the basis of the simple two-step mechanism, improvement in yield would be expected at increased temperature because the ratio of k_1 to k_2 increases with increasing temperature. Thus xylose disappearance rates and furfural appearance rates and yields were determined over the wide temperature range of 160° to 280° C. Sulfuric acid in the concentration range 0.8 N to 0.00625 N was used as the catalyst. Initial concentration of xylose was varied from 200 grams to 3.125 grams per liter.

Experimental Techniques and Analytical Methods

Rate data were obtained from small batch samples of solutions reacted isothermally for various lengths of time. Batch reactors were made from 3-ml. borosilicate glass tubing, which had the necessary high mechanical strength, acid resistance, and small size to enable rapid heat transfer. Sealed ampoules, partially filled with water, failed in the range 395° to 410° C., a range that corresponds to a vapor pressure of about 3,000 p.s.i. Thus, under the most severe experimental conditions (about 1,000 psi), a safety factor of three was in effect. When quenched, borosilicate glass ampoules withstood thermal shocks in excess of 260° C. without failures.

A hypodermic syringe pipet, equipped with suitable stops, was used

[1] Presented at the 132nd Annual Meeting, American Chemical Society, Sept. 9–13, 1957, N.Y., N.Y. Part I of this series appeared in Sept., 1958 (Vol. VIII, No. 9.)
[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
[3] Numbers in parentheses refer to the Literature Cited at the end of this paper.

to charge the ampoules with an exact amount of solution. Six-inch lengths of tubing were constricted at one end, and the constricted tip was inserted into the tip of the syringe for loading. No leakage around the annular space occurred because of the high capillary forces present. The constricted end was then flame-sealed after the liquid was permitted to move back from the tip. The solution was then shaken down to the sealed end, and the tube was constricted near its other end, chilled, evacuated, and then sealed. Sufficient void space was allowed for thermal expansion of the liquid. Tests showed that the loading operation was reproducible to 0.001 ml. with 0.25 ml. samples. About 200 of these ampoules could be prepared and charged in a day.

For samples reacted for less than 1½ minute, 1-ml. Pyrex tubing was used to make the ampoules. These were charged with about 0.02 ml. of solution by dipping the tubing into the solution. The amount of the sample was determined by weighing the ampoule before and after it was filled.

Ampoules were reacted in a bath of hydrogenated cotton-seed oil, controlled to within ± 0.1° C., and quenched in an oil bath. Failure can result from tiny imperfections in the glass or because the void in the ampoule is not sufficient to permit liquid expansion. Although the ampoules are small, explosions are violent and a broken ampoule can become a dangerous missile. For this reason, the operator was protected by a portable shield placed in front of the bath.

Analyses for xylose were made with the method developed by Nelson (9) and Somogyi (12). Spectrophotometric absorption in ultraviolet light by aqueous furfural formed the basis of furfural analysis. This method is described by Stone and Blundell (13). At 276 millimicrons, absorption follows Beer's law, and gives an extinction coefficient of 14,850 liters per gram-mole per cm. Because of the interference of other constituents in the reacted solution, it was necessary to separate the furfural by distillation. When the ampoule's contents are diluted to 60 ml in a 200-ml distillation flask and 45 to 50 ml of distillate are collected, the furfural is recovered with less than 1 per cent loss.

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Wayne Neill (not shown) is professor of chemical engineering at the University of Wisconsin.

Data and Mathematical Correlations

Xylose Disappearance: Data for the rate of xylose disappearance were collected at an initial xylose concentration of 0.666 gram-mole per liter over the entire temperature and acid concentration range. Xylose disappearance is of first order:

$$\frac{d\,C_X}{dt} = -k_1 C_X \qquad (1)$$

where C_X is xylose concentration (gram-moles per liter), t is time (minutes) and k_1 has units of reciprocal minutes. With the initial condition, at $t = O$, $C_X = C_{X_o}$, equation (1) may be integrated to

$$C_X^* = \frac{C_X}{C_{X_o}} = e^{-k_1 t} \qquad (2)$$

The quantity C_X^*, as defined in equation (2), is dimensionless and is unity at $t = O$. From the slope of the straight line obtained when $ln\ C_X^*$ is plotted against time, the rate constant k_1 is calculated according to

$$k_1 = -\frac{d \ln C_X^*}{dt}$$

The Arrhenius plot became linear when the effect of liquid expansion was taken into account. Fig. 1 shows $log\ k_1/\delta$ versus reciprocal absolute temperature. The factor δ is the specific gravity of water at the temperature involved referred to water at 30° C. The introduction of δ in effect corrects the initial concentration measured as gram-moles per liter at room temperature to the concentration at the reaction temperature. Parallel straight lines were obtained for 0.8, 0.4, 0.2, and 0.1 N sulfuric acid. From the slope of these lines, an energy of activation of 33,560 calories per gram-mole was calculated and k_1 was expressed as

$$k_1/\delta = K' e^{\frac{-33{,}560}{RT}} \qquad (3)$$

To the first approximation, the constant K' is directly proportional to acid concentration C_{H+}, and equation (3) is rewritten as

$$k_1/\delta = K\gamma_X C_{H^+} e^{\frac{-33{,}560}{RT}} \qquad (4)$$

The constant γ_X is defined to be unity for all temperatures at the acid concentration of 0.8 N. At 200° C. and at 0.8 N sulfuric acid,

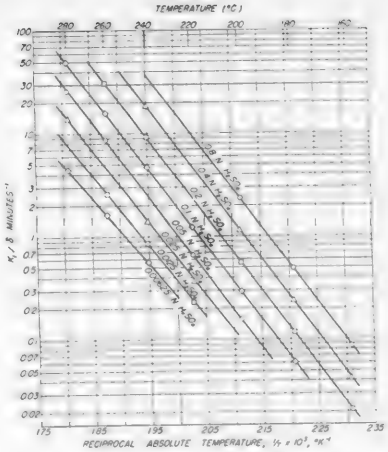


Fig. 1.—Effect of temperature on k_1 at various acid concentrations. Initial xylose concentration = 0.666 gram-mole per liter. The constant, k_1, is the xylose disappearance rate constant, and δ is the ratio of the specific volume of water at 30° C. to the specific volume of water at the given temperature. Curves are equation (6) or (7).

WHAT THIS RESEARCH MEANS

The development of an economical chemical process for utilizing wood residues would make it possible to clear unproductive forest lands (an area exceeding 50,000,000 acres in the United States), which could be replanted to yield trees of value for lumber, pulp, and cellulosic residues suitable for continued chemical production. It seems reasonable to assume that, with our present technological tools and with sufficient research effort, suitable processes can be made available.

Wood as a chemical raw material is primarily a source of hexose and pentose sugars. The prehydrolysis of cellulosic material with the separation of pentose in solution has long been recognized as a desirable step in any chemical utilization process. The development of economic methods of processing the dilute solutions of xylose obtained in this way is an important part of the larger problem of chemical utilization. Economic and technical evaluation of any suggested scheme must be based on data such as presented here.

This information on the yield of furfural and its rate of production from xylose in various solutions will be of interest to all concerned with utilization of cellulosic residues. It will be of particular interest to those wood-using industries that have by-product streams containing xylose. Among these are included: sulfite-pulping, prehydrolysis kraft-pulping, and the hardboard industries.

Editor

When equation (4) is divided by equation (5), there is obtained

$$k_1/\delta = 2.32\ \text{min.}^{-1} = K(1.000)(0.8)\ e^{\frac{-(33{,}560)}{(1.987)(473.1)}} \qquad (5)$$

$$k_1 = 2.90\,\delta\gamma_X C_{H^+} e^{\left(-35.70\frac{4731.1 - T}{T}\right)}\ \text{min.}^{-1} \qquad (6)$$

With the curves of Fig. 1, γ_X at other conditions established (Fig. 2).

Equation (6) then relates k_1 to temperature and acid concentration at an initial xylose concentration of 0.666 gram-mole per liter over the range of conditions indicated in Fig. 1. The average deviation of equation (6) from experimental values of k_1 is 1.27 per cent.

When the initial xylose concentration C_{X_o} was varied, observed changes in k_1 were proportional to changes in the acid-water ratio in the solution. In these tests, solutions were prepared in such a manner that a given volume of solution contained the same amount of acid regardless of the value of C_{X_o} for a particular acid concentration. Thus a solution with 100 grams of xylose per liter would have less water and a higher acid-water ratio than a solution containing 50 grams of xylose per liter.

If k_1 depends upon acid-water ratio, k_1 would be higher in the first solution, which would conform to the observed effect. With the use of xylose solution densities, the acid-water ratio was calculated, and a constant α, the acid-water ratio in a solution of initial xylose concentration C_{X_o} divided by the acid-water ratio in a solution of zero C_{X_o}, was calculated:

C_{X_o} Gm.-mole per liter	α
1.332	1.142
.666	1.067
.333	1.033
.1666	1.015
.0833	1.006
.0416	1.003
.0208	1.002
0	1.000

Equation (6) is then made general for all initial conditions by multiplying the right side by $\alpha/1.067$. Thus,

$$k_1 = 2.72\,\alpha\delta\gamma_X C_{H^+} e^{-35.70\left(\frac{4731.1 - T}{T}\right)} \qquad (7)$$

The variation of k_1 with C_{X_o} was determined at 160°, 200°, and 240° C. At each temperature the values of k_1 calculated from equation (7) were in excellent agreement with observed values.

The hypothesis that k_1 depends upon the acid-water ratio is further supported by the data of Kirby (6). Kirby studied the first-order disappearance of glucose in dilute sulfuric acid and found that the rate constant did not vary with initial glucose concentration. However, in these studies, solutions were prepared by adding acid of desired concentration to a flask containing a weighed amount of dry sugar, so that acid-water ratio was the same for every solution regardless of initial sugar concentration.

Furfural Disappearance

When acidified aqueous furfural was allowed to react for various lengths of time, furfural decomposed in such a way that a plot of $ln\ C_F$ versus time gave a straight line, which indicates first-order disappearance:

$$\frac{dC_F}{dt} = -k_2 C_F \qquad (8)$$

or

$$C_F' = \frac{C_F}{C_{F_o}} = e^{-k_2 t}$$

For rate data obtained at an initial furfural concentration of 0.0478 gram-mole per liter, values of k_2 were obtained, and, in a manner similar to that used for k_1, an energy of activation of 22,070 calories per gram-mole was calculated, and the following equation was developed:

$$k_2 = 0.1070\delta\gamma_F C_{H^+} e^{-23.48\left(\frac{4731.1 - T}{T}\right)} \qquad (9)$$

Values of γ_F are given in Fig. 4. Equation (9) is experimentally supported for the conditions 160° to 240° C. and 0.8 to 0.05 sulfuric acid, with 1.81 per cent average deviation.

It may be seen that γ_F and γ_X are not in perfect agreement. Although it is certain that each γ contains, as a contributing factor, the hydrogen ion activity coefficient, there must be additional contributing factors that are different in each system. Emmett (3) points out that in acid-base catalysis the observed reaction rate constant is, in general, the sum of three, thus:

$$k = k_o + k_{H^+} + k_{HO^-}$$

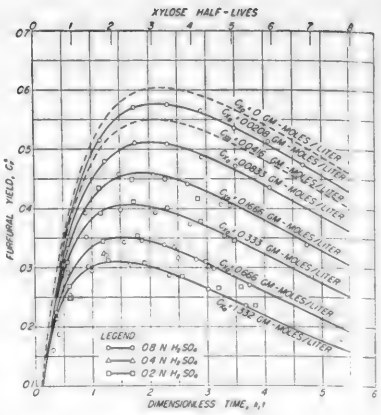


Fig. 4.—Effect of initial xylose concentration on furfural yields at 160° C. Curves are equation (15) or (18).

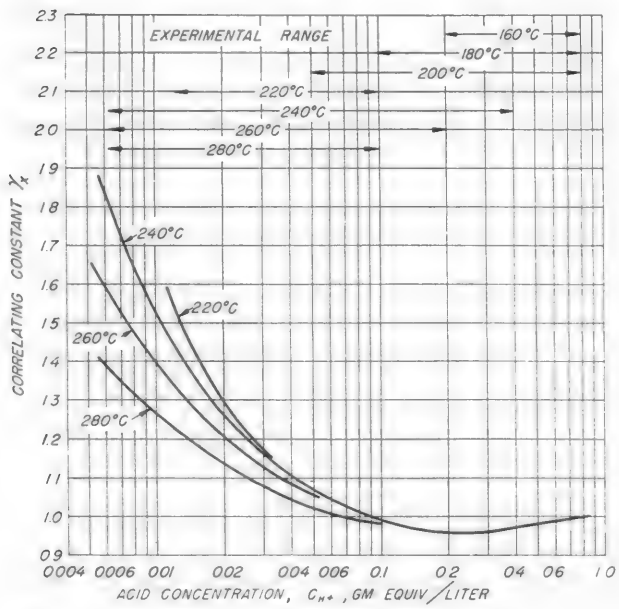
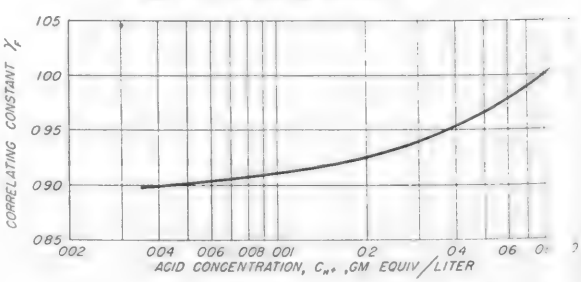


Fig. 2. Correlating constant —γ_X.

Fig. 3.—Correlating constant —γ_F.



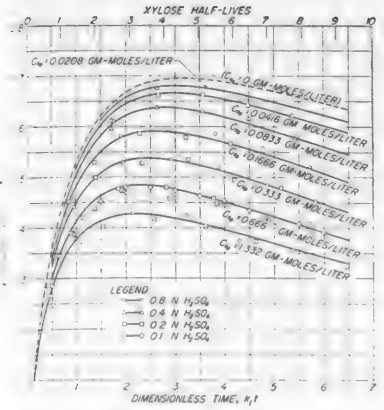


Fig. 5.—Effect of initial xylose concentration on furfural yields at 200° C. Uppermost dashed curve gives yield predicted by simple two-step mechanism, equation (12). Other curves are equation (15) or (18).

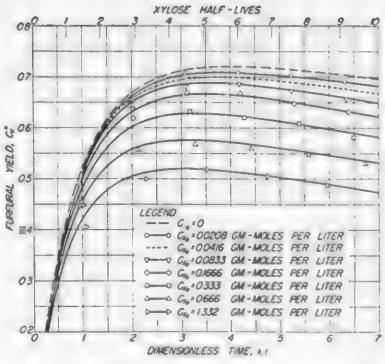

XYLOSE HALF-LIVES
FURFURAL YIELD, C_F*
DIMENSIONLESS TIME, k₁t
LEGEND
C_x = 0
C_x = 0.0208 GM-MOLES PER LITER
C_x = 0.0416 GM-MOLES PER LITER
C_x = 0.0833 GM-MOLES PER LITER
C_x = 0.1666 GM-MOLES PER LITER
C_x = 0.333 GM-MOLES PER LITER
C_x = 0.666 GM-MOLES PER LITER
C_x = 1.332 GM-MOLES PER LITER

Fig. 6.—Effect of initial xylose concentration on furfural yields at 240° C. Acid concentration = 0.025 N sulfuric acid. Curves are equation (18).

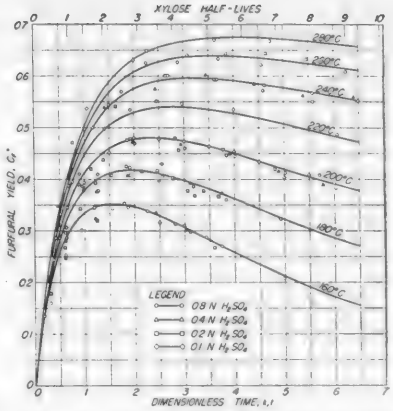


Fig. 7.—Effect of temperature on furfural yields. Initial xylose concentration = 0.666 gram-mole per liter. Curves are equation (15) or (18).

where k_0 is a rate constant for spontaneous reaction, and k_{H+} and k_{OH-} are acid- and base-catalyzed reaction rate constants. Thus, in general, k may vary in a number of different ways with changes in pH, depending upon the relative magnitudes of these constants.

When initial furfural concentration was varied, large changes in k_2 occurred. For example at 220° C. with 0.4 N sulfuric acid, the following values were found:

C_{F_0} Gm.-mole per liter	k_2 Min.$^{-1}$
0.0239	0.0805
.0478	.0900
.0957	.1043
.1915	.1186

These solutions were far too dilute for such large variations in k_2 to be explained in the same way in which the variations of k_1 with C_{X_0} were accounted for. This variation will be discussed later in the paper.

Furfural Formation

It is helpful in analyzing furfural appearance data to refer to the results that would be expected for the simple two-step mechanism

$$X \xrightarrow{k_1} F \xrightarrow{k_2} D$$

where X is xylose, F is furfural, and D is the destruction product. This mechanism gives the following rate equation for furfural appearance:

$$\frac{dC_F}{dt} = k_1C_X - k_2C_F$$

or

$$\frac{dC_F^*}{dt} = k_1C_X^* - k_2C_F^* \qquad (10)$$

where $C^* = C/C_{X_0}$. When equation (2) is inserted into equation (10) and (10) is integrated with the initial condition, at $t = 0$, $C_F^* = 0$, there results

$$C_F^* = \frac{k_1}{k_1 - k_2}(e^{-k_2 t} - e^{-k_1 t}) \qquad (11)$$

or

$$C_F^* = \frac{1}{1 - a}(e^{-ak_1 t} - e^{-k_1 t}) \qquad (12)$$

where $a = k_2/k_1$. If k_1 and k_2 vary (with acid concentration) in the same way, a is independent of acid concentration and a graph of C_F^* versus the "dimensionless time" variable k_1t gives the same curve for all acid concentrations. For this simple mechanism, equation (11) or (12) indicates no change of C_F^* with initial xylose concentration.

The observed variation of C_F^* with k_1t is shown in Figs. 4, 5, 6, and 7. At acid concentrations of 0.1 N and above, furfural yield data for all acid concentrations fall on the same curve. In this respect, observed behavior with acid concentration agrees with the behavior in equation (12) where a is independent of acid concentration. However, furfural yields show large variations with C_{X_0}, the yield increases to a limit as C_{X_0} goes to zero.

A successful correlation of observed yields at acid concentrations of 0.1 N and above results when the rate equation (10) is modified by the addition of a term. When equation (10) is divided by k_1 and the term $bC_X^*C_F^*$ is subsequently subtracted from the right side, the following is obtained:

$$\frac{dC_F^*}{d(k_1t)} = C_X^* - aC_F^* - bC_X^*C_F^* \qquad (13)$$

A mechanism that leads to a rate equation of the same form will be discussed later. From equation (2),

$$d(k_1t) = -\frac{dC_X^*}{C_X^*}$$

so that equation (13) may be expressed as

$$\frac{dC_F^*}{dC_X^*} - a\frac{C_F^*}{C_X^*} - bC_F^* = -1 \qquad (14)$$

With the initial condition, $C_F^* = 0$ at $t = 0$, equation (14) may be integrated to give

Table 1.—THE FUNCTION G(a,X)

X	a = 0.00	0.02	0.04	0.06	0.08	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30
0.0	1.0000	1.0204	1.0416	1.0638	1.0870	1.1111	1.1364	1.1628	1.1905	1.2195	1.2500	1.2821	1.3158	1.3514	1.3889	1.4286
0.2	0.9063	0.9258	0.9461	0.9672	0.9893	1.0124	1.0366	1.0619	1.0885	1.1164	1.1457	1.1765	1.2091	1.2434	1.2796	1.3180
0.4	.8242	.8428	.8621	.8823	.9035	.9256	.9488	.9732	.9987	1.0255	1.0537	1.0835	1.1149	1.1480	1.1831	1.2202
0.6	.7523	.7697	.7883	.8076	.8279	.8492	.8714	.8948	.9194	.9453	.9725	1.0012	1.0316	1.0636	1.0976	1.1336
0.8	.6883	.7053	.7231	.7417	.7612	.7816	.8050	.8256	.8493	.8742	.9005	.9283	.9577	.9887	1.0217	1.0566
1.0	.6321	.6484	.6655	.6833	.7021	.7217	.7424	.7641	.7870	.8111	.8366	.8635	.8919	.9221	.9541	.9881
1.2	.5823	.5980	.6144	.6316	.6496	.6686	.6885	.7095	.7317	.7550	.7796	.8057	.8333	.8626	.8937	.9268
1.4	.5381	.5532	.5690	.5856	.6030	.6213	.6406	.6609	.6823	.7049	.7288	.7541	.7809	.8094	.8397	.8719
1.6	.4988	.5133	.5286	.5446	.5614	.5791	.5977	.6174	.6381	.6601	.6833	.7079	.7340	.7617	.7912	.8226
1.8	.4637	.4777	.4924	.5079	.5241	.5413	.5593	.5784	.5985	.6198	.6424	.6663	.6917	.7188	.7485	.7782
2.0	.4323	.4459	.4601	.4750	.4908	.5074	.5249	.5434	.5630	.5837	.6056	.6289	.6537	.6800	.7081	.7381
2.2	.4042	.4173	.4310	.4455	.4608	.4769	.4939	.5119	.5309	.5510	.5724	.5951	.6193	.6450	.6725	.7018
2.4	.3789	.3915	.4049	.4189	.4337	.4494	.4659	.4834	.5019	.5215	.5424	.5645	.5881	.6133	.6401	.6688
2.6	.3560	.3683	.3812	.3949	.4093	.4245	.4406	.4576	.4756	.4948	.5151	.5368	.5598	.5844	.7107	.6388
2.8	.3354	.3473	.3599	.3731	.3871	.4019	.4176	.4342	.4518	.4704	.4903	.5115	.5340	.5581	.5838	.6113
3.0	.3167	.3283	.3405	.3534	.3670	.3814	.3967	.4128	.4300	.4483	.4677	.4884	.5104	.5340	5592	.5862

$$C_F^* = e^{bC_X^*}\left[G(a,b)e^{-ak_1t} - C_X^*\,G(a,bC_X^*)\right] \qquad (15)$$

where

$$G(a,x) = \sum_{n=0}^{\infty} (-1)^n \frac{x^n}{(n+1-a)\,n}$$

The function *G(a,x)* was evaluated for appropriate ranges of *a* and *x*, and values are given in Table 1.

With appropriate values of *a* and *b*, equation (15) was used to calculate the curves of Figs. 4, 5, and 7. Its success is evident in Fig. 7 where, for an acid concentration of 0.1 N, maximum C_F^* occurs at 2.7 hours at 160° C. and at 6.4 seconds at 280° C. Fig. 7 also illustrates the advantage of the use of the "dimensionless time" variable k_1t. Data for a large range of rates are presented on the same graph, which facilitates the study of trends.

The appropriate values of *a* and *b* were obtained from data at the end portion of each yield curve, where C_X^* is very small and equation (15) reduces to

$$C_F^* = G(a,b)e^{-ak_1t}$$

A plot of $ln\ C_F^*$ versus k_1t in this region gives a straight line with a slope of (—*a*) and an intercept of $ln\ G(a,b)$. With $G(a,b)$ and *a* established in this way, *b* was obtained from Table 1.

Variations of *a* and *b* with temperature and initial xylose concentration are shown in Figs. 8 and 9. Values of *a* and *b* for $C_{X_o} = 0$ were obtained by extrapolation. Since the curve, C_F^* versus k_1t, does not change with acid concentration, both *a* and *b* are independent of acid concentration. Curves for $C_{X_o} = 0$ were calculated with equation (15) and the value of *a* and *b* obtained by extrapolation; these are designated by dashed lines in Figs. 4 and 5.

Fig. 5 also shows for comparison the curve calculated with equation (12) for the simple two-step mechanism. The value of *a* used in this calculation was that for $C_{X_o} = 0$.

Comparison of equation (7) for k_1 and equation (9) for k_2 indicates that *a* should vary slightly with acid concentration. When equation (9) is divided by equation (7), there is obtained

$$a = \frac{k_2}{k_1} = \frac{0.0393}{a}\,\frac{\gamma_F}{\gamma_X}\,e^{12.22\left(\frac{473.1-T}{T}\right)} \qquad (16)$$

Since γ_F and γ_X do not vary with acid concentration in the same manner, equation (16) indicates a small dependence of *a* upon acid concentration. However, k_2 is small compared with k_1, and it turns out that C_F^* calculated from equation (15) is insensitive to errors in *a*. In dilute solution, *a* is near unity, and if γ_X and γ_F are assumed to be equal, equation (16) becomes

$$a = 0.0393\,e^{12.22\left(\frac{473.1-T}{T}\right)} \qquad (17)$$

When *a*, obtained from the application of equation (15) to the yield data, was extrapolated to zero initial xylose concentration, a value near that given by equation (17) was obtained; therefore; equation (17) was used for *a* in infinitely dilute solution (curve 1, Fig. 8).

With acid concentrations more dilute than 0.1 N, furfural yields drop below those given by equation (15). Equation (15) was modified to agree with observed yields at these acid concentrations by including the correlating factor *d*; thus

$$C_F^* = d\,e^{bC_X^*}\,G(a,b)\,e^{-ak_1t} - C_X^*\,G(a,bC_X^*) \qquad (18)$$

The constant *d* is given in Fig. 10. A comparison of yields given by equation (18) with observed yields is illustrated in Fig. 11.

Equation (18) is then more general than equation (15), for it is valid over the entire range of variables used in these tests. In differential form, which is required for calculating yields under

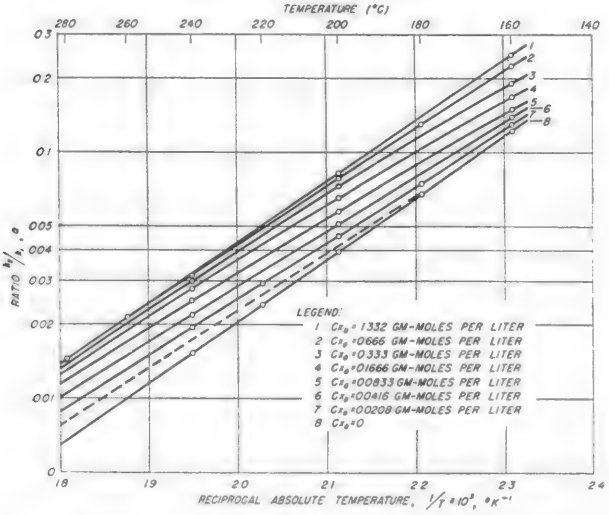

TEMPERATURE (°C)
280 260 240 220 200 180 160 140
RATIO k_2/k_1, a
RECIPROCAL ABSOLUTE TEMPERATURE, $1/T \times 10^3$, °K^{-1}
LEGEND:
1 C_{X_o} = 1332 GM-MOLES PER LITER
2 C_{X_o} = 0666 GM-MOLES PER LITER
3 C_{X_o} = 0333 GM-MOLES PER LITER
4 C_{X_o} = 01666 GM-MOLES PER LITER
5 C_{X_o} = 00833 GM-MOLES PER LITER
6 C_{X_o} = 00416 GM-MOLES PER LITER
7 C_{X_o} = 00208 GM-MOLES PER LITER
8 C_{X_o} = 0

Fig. 8.—The ratio, k_2/k_1, a. Points in figure indicate points at which experimental work was done.

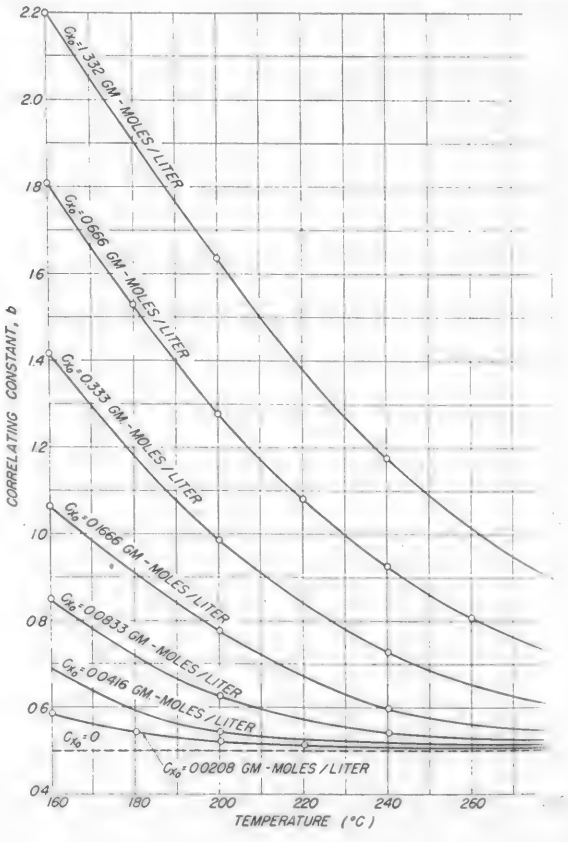


Fig. 9.—Correlating constant, b. Points in figure indicate points at which experimental work was done.

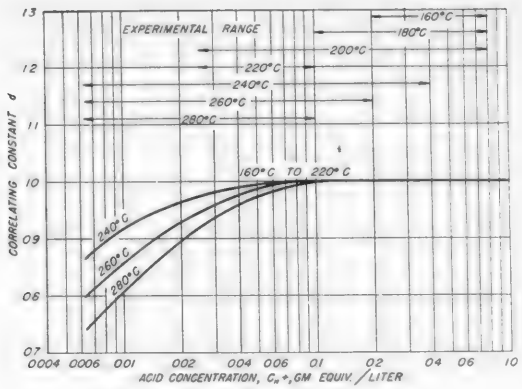


Fig. 10.—Correlating constant, d.

nonisothermal conditions, this general correlating equation is

$$\frac{dC_F^*}{d(k_1t)} = dC_X^* - aC_F^* - bC_X^*C_F^* \qquad (19)$$

It differs from equation (13) in the appearance of d (a factor of unity or less) before C_X^*, which indicates that not all of the xylose is converted to furfural in very dilute acid. This may be the result of a hydroxyl-ion catalyzed destruction of xylose to products other than furfural.

Possible Mechanisms

In tests of furfural disappearance, there was a marked effect of initial furfural concentration on the rate constant k_2. Consistent with this effect is the large variation of a with initial xylose concentration shown in Fig. 8. In very concentrated solution, a is approximately twice the value of a in infinitely dilute solution. A mechanism was found that gives a possible explanation of this behavior.

In the acid-catalyzed destruction of furfural, furfural would disappear at a faster rate in more concentrated solution if the following reactions were taking place:

$$F \xrightarrow{k_2'} S \xrightarrow{k_3} D_1, \qquad F \xrightarrow{} D_2, \qquad S \xrightarrow{k_4} D_2$$

where S is an intermediate product and D_1 and D_2 are destruction products. The rate constant k_4 is a second-order rate constant for the interaction of F and S. The differential equations that describe this mechanism are

$$\frac{dC_S'}{dt} = k_2'C_F' - k_3C_S' - k_4C_{F_o}C_F'C_S' \qquad (20)$$

and

$$\frac{dC_F'}{dt} = k_2'C_F' - k_4C_{F_o}C_F'C_S' \qquad (21)$$

where $C' = C/C_{F_o}$. In very dilute solution, equation (21) reduces to

$$\frac{dc_F'}{dt} = -k_2'C_F' \qquad (22)$$

and furfural disappearance is truly first-order. In infinitely concentrated solution, C_S' would be very small at all times and dC_S'/dt and k_3C_S' would be small compared with the other terms in equation (20). When these are set equal to zero, C_S' is obtained algebraically:

$$C_S' = k_2'/k_4C_{F_o} \qquad (23)$$

Substitution of equation (23) into equation (21) gives

$$\frac{dC_F'}{dt} = -2k_2'C_F' \qquad (24)$$

which shows apparent first-order disappearance of furfural. The apparent first-order rate constant in equation (24) is exactly twice the true first-order constant in equation (22).

The behavior between the two concentration limits makes it difficult to distinguish between this mechanism and true first-order disappearance. It is evident that the reaction is more closely described by this mechanism than by a simple first-order mechanism. In the correlation of yield data, however, it is adequate to treat furfural disappearance as though it were truly of first order, and take into account the effect of initial xylose concentration on the value of the rate constant.

It was deduced earlier that the reaction mechanism was probably of the following form:

$$X \xrightarrow{k_1} (\text{Intermediates}) \xrightarrow{} F \xrightarrow{k_2} D_1, \qquad (\text{Intermediates}) \xrightarrow{} D_2$$

Further evidence to support this deduction was obtained in these tests when furfural yields from xylose were determined with furfural added initially to the solution. The addition of furfural did not affect the value of k_1, which indicates that no interaction occurs between xylose and furfural. However, the yield of furfural from xylose was reduced, which supports the hypothesis that a yield-reducing side reaction that involves furfural does occur. The reduction increased with increasing amounts of added furfural.

The simplest case where only one intermediate occurs to an appreciable extent is:

$$X \xrightarrow{k_1} I \xrightarrow{k_5} F \xrightarrow{k_2} D_1, \qquad I \xrightarrow{} D_2, \qquad F \xrightarrow{k_6} D_2$$

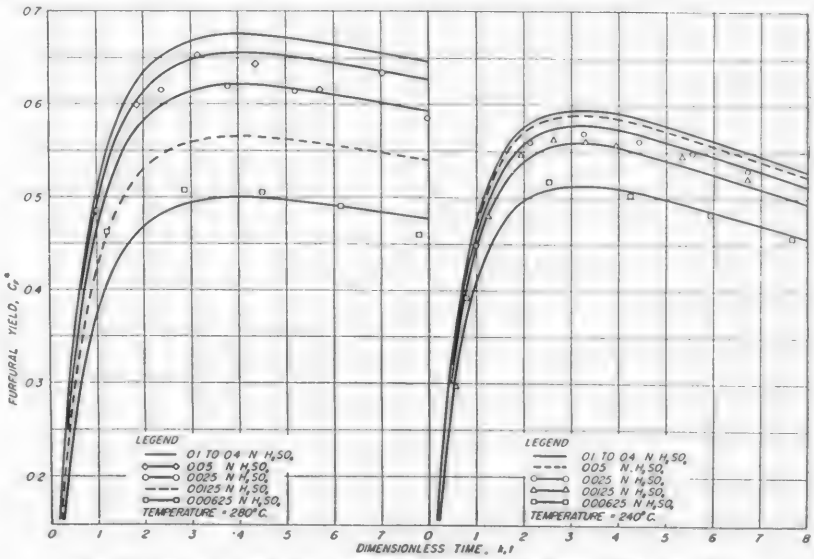


Fig. 11.—Effect of dilute sulfuric acid on furfural yields at 240° and 280° C. Curves are equation (18).

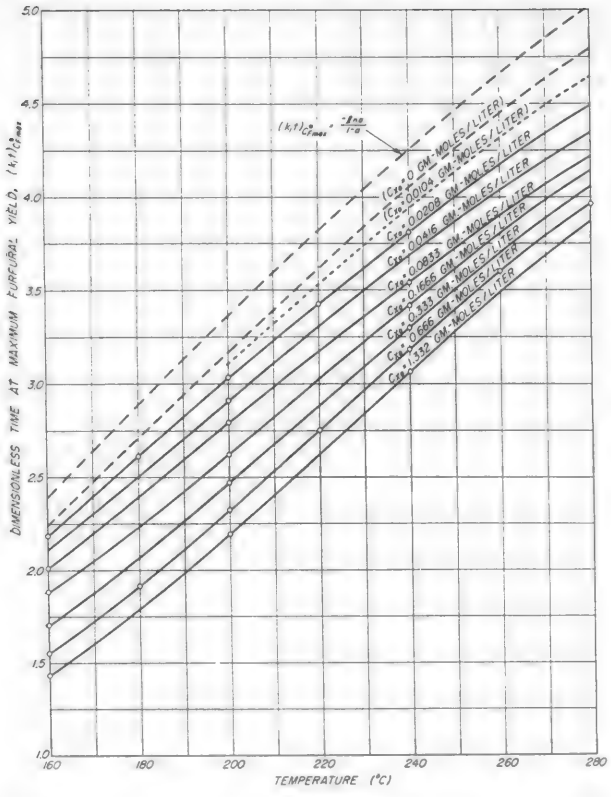

DIMENSIONLESS TIME AT MAXIMUM FURFURAL YIELD, $(k_1t)_{C_{F\,max}}^*$
TEMPERATURE (°C)
$(k_1t)^*_{C_{F\,max}} = \frac{-\ln a}{1-a}$
C_{X_0} = 0 GM-MOLES/LITER
C_{X_0} = .00104 GM-MOLES/LITER
C_{X_0} = .00208 GM-MOLES/LITER
C_{X_0} = .00416 GM-MOLES/LITER
C_{X_0} = .00833 GM-MOLES/LITER
C_{X_0} = .01666 GM-MOLES/LITER
C_{X_0} = .0333 GM-MOLES/LITER
C_{X_0} = .0666 GM-MOLES/LITER
C_{X_0} = .1332 GM-MOLES/LITER

Fig. 12.—Dimensionless time at maximum furfural yield, $(k_1 t)C_F^*$ max. Points in figure indicate points at which experimental work was done. Uppermost dashed curve gives value predicted by simple two-step mechanism, equation (12).

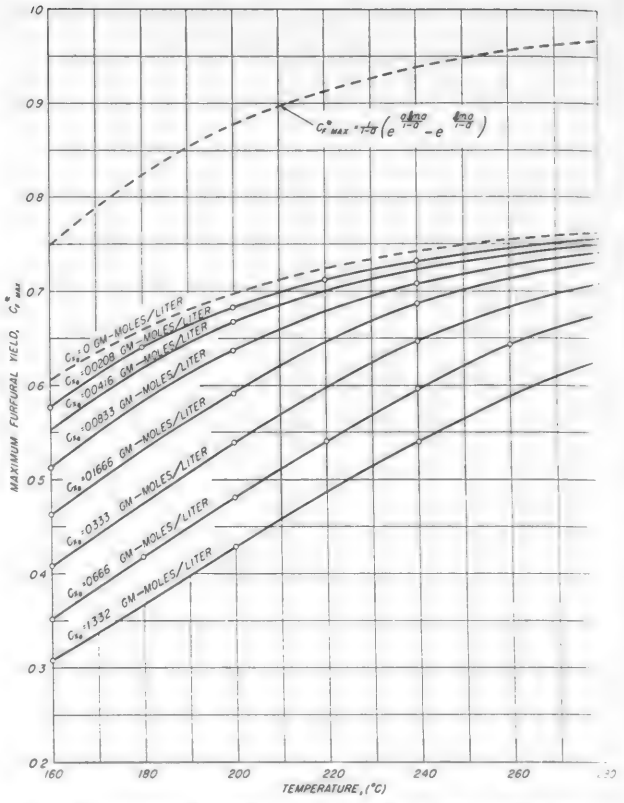

MAXIMUM FURFURAL YIELD, C_F^* max
TEMPERATURE, (°C)
$C_{F\,MAX}^* = \frac{a}{1-a}\left(e^{\frac{a \ln a}{1-a}} - e^{\frac{\ln a}{1-a}}\right)$
C_{X_0} = 0 GM-MOLES/LITER
C_{X_0} = .00208 GM-MOLES/LITER
C_{X_0} = .00416 GM-MOLES/LITER
C_{X_0} = .00833 GM-MOLES/LITER
C_{X_0} = .01666 GM-MOLES/LITER
C_{X_0} = .0333 GM-MOLES/LITER
C_{X_0} = .0666 GM-MOLES/LITER
C_{X_0} = .1332 GM-MOLES/LITER

Fig. 13.—Maximum furfural yield, C_F^* max. For acid concentrations below 0.1 N sulfuric acid, multiply C_F^* max. by d in Fig. 11. Points in figure indicate points at which experimental work was done. Uppermost dashed curve gives C_F^* max. as predicted by simple two-step mechanism; equation (12).

and the differential equations for this mechanism are:

$$\frac{dC_I^*}{dt} = k_1 C_X^* - k_2 C_I^* - k_6 C_{X_0} C_I^* C_F^* \qquad (25)$$

and

$$\frac{dC_F^*}{dt} = k_3 C_I^* - k_4 C_F^* - k_6 C_{X_0} C_I^* C_F^* \qquad (26)$$

where $C^* = C/C_{X_0}$. Equation (26) indicates that the furfural yield curve has zero initial slope; for initially C_I^* and C_F^* are zero. Furthermore, if C_I^* becomes appreciably large, a sizable portion at the beginning of the furfural yield curve would have a positive curvature. Since this behavior is not observed, it is apparent that an intermediate must have only transient existence, and never accumulate in appreciable quantities.

If C_I^* is very small, then dC_I/dt must be very small compared with the other terms in equation (25), and an approximate solution of equation (25) may be obtained by setting dC_I^*/dt equal to zero. Then

$$C_I^* = \frac{C_F^*}{k_5 + k_6 C_{X_0} k_1 C_X^*} \qquad (27)$$

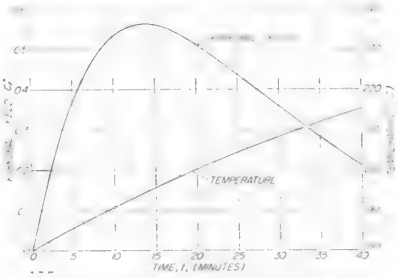


Fig. 14.—Yield of furfural under non-isothermal conditions. Initial xylose concentration = 0.1666 gram-mole per liter; acid concentration = 0.2 N sulfuric acid. The yield curve was obtained by numerical integration of equation (13).

when equation (27) is substituted into equation (26) and then is divided by k_1, there is obtained

$$\frac{dC_F^*}{d(k_1t)} = \frac{k_3 C_X^*}{k_5 + k_6 C_{X_0} C_F^*} - aC_F^* - \frac{k_6 C_{X_0} C_X^* C_F^*}{k_5 + k_6 C_{X_0} C_F^*} \qquad (28)$$

Then if $k_6 C_{X_0} C_F^*$ is small compared with k_5 (true in very dilute solution), equation (28) becomes

$$\frac{dC_F^*}{d(k_1t)} = C_X^* - aC_F^* - b'C_X^* C_I^* \qquad (29)$$

where

$$b' = k_6 C_{X_0}/k_5$$

Equation (29) is of the same form as equation (13), from which the correlation was developed. The fact that b is independent of acid concentration can be interpreted to be a result of both k_5 and k_6 being similarly dependent upon acid concentration. Equations (29) and (13) are not identical, for b in equation (13) does not go to zero with decreasing C_{X_0} as indicated in equation (29), but decreases to a limit near 0.5 at all temperatures. Thus, b is simply a correlating parameter with behavior approximating that of $(b'$. Further elucidation of the mechanism would require experimental information on the intermediates.

An attempt was made to detect directly the presence of intermediate. Equation (27) predicts that maximum

concentration would occur before very much of the xylose is reacted. A solution of xylose was reacted at 200° C. to about 7 per cent decomposition of the xylose and was spotted on chromatographic paper. The spot was irrigated with a butanol-pyridine-water solvent system. After the solvent front had advanced 18 inches, the paper was dried and sprayed with ammoniacal silver nitrate to develop the spots of separate solutes.

In addition to the very intense xylose spot at an R_f value (ratio of spot distance to solvent front distance) of 0.238, other spots were found at R_f values of 0.074, 0.135, 0.331, 0.487, 0.622, and 0.712. The spots at 0.074 and 0.135 were probably xylose reversion products (disaccharides and higher polymers). When an unreacted solution of acidified xylose was similarly chromatographed, these spots were also obtained. None of the remaining four spots could be furfural because furfural evaporates from the paper when the spotted samples dry. Also, the reaction had not proceeded far enough for appreciable amounts of furfural decomposition products to accumulate.

No attempt was made at the time of these tests to recover the separated solutes for identification. However, it is felt that this technique for determining the mechanism of the reaction shows a great deal of promise, and it is being given further attention.

Use of Correlation

These tests were conducted to correlate reaction rates and yields with experimental conditions over ranges sufficiently wide to permit accurate selection of optimum reacting conditions for the production of furfural. Although there may be differences between the behavior of pure xylose solutions and those which might be of commercial interest, these results will serve to approximate the optimum processing conditions and predict trends with changes in operating variables. The process designer is interested in the maximum furfural yield and the time at which maximum yield occurs.

The value of k_1t at maximum furfural yield, $(k_1t)_{C_{F*max}}$, is obtained by setting $dC_{F*}/d(k_1t)$ in equation (13) equal to zero. When equation (15) for C_{F*} and equation (2) for C_{X*} are inserted into the resulting equation, $(k_1t)_{C_{F*max}}$ appears implicitly and is obtained by graphical solution. The results are given in Fig. 12. Maximum furfural yield C_{F*max} (Fig. 13) is obtained from equation (15) with the use of $(k_1t)_{C_{F*max}}$ in Fig. 12. The time at which maximum yield occurs is obtained by dividing $(k_1t)_{C_{F*max}}$ by k_1.

For comparison, $(k_1t)_{C_{F*max}}$ and C_{F*max} for the simple two-step mechanism (equation (12)) are given in Figs. 12 and 13. When dC_{F*}/dt in equation (10) is set equal to zero and solution is made for $(k_1t)_{C_{F*max}}$, there results

$$(k_1t)_{C_{F*max}} = \frac{-\ln a}{1-a} \quad (30)$$

where $a = k_2/k_1$; and equation (30) used with equation (12) gives

$$C_{F*max} = \frac{1}{1-a}\left(e^{\frac{-\ln a}{1-a}} - e^{\frac{-a \ln a}{1-a}}\right) \quad (31)$$

The value of a given by equation (17) was used in equation (30) and (31) for these curves in Figs. 12 and 13.

For acid concentrations below 0.1 N sulfuric acid, C_{F*max} is obtained by multiplying the value in Fig. 14 by the constant d in Fig. 8.

The fact that equation (15) was not obtained from the actual reaction mechanism suggests that it would be better to use a correlating equation of simpler form. For example, it was found that the following equation could successfully correlate the yield data:

$$= G(e^{-k_2t} - e^{-Dt})$$

where G is $G(a,b)$ in equation (15), k_2 is the same rate constant as before, and D is an empirically determined constant that has values in the order of the magnitude of k_1. The principal advantage of the correlation used is that it is also expressed in differential form, and can be used for reactions that proceed under nonisothermal conditions. The results of a run made under nonisothermal conditions are shown in Fig. 14. Seven ampoules, with solution samples containing 0.166 gram-mole of xylose and 0.2 N sulfuric acid, were placed in the bath at 180° C. The temperature was allowed to rise (Fig. 14), and ampoules were removed at various intervals. Simpson's rule was used to integrate equation (2) numerically for C_{X*}. The curve in Fig. 14 was obtained by numerical integration of equation (14) with the modified Euler method (8). The agreement between the experimental points and the curve derived from equation (13) illustrates the advantage of presenting the correlation in the form used. It constitutes a check on the validity of using these data, gathered under isothermal conditions for nonisothermal conditions, and emphasizes the utility of the correlation when applied to the problem of commercial reactor design.

Summary

The production of furfural holds promise for the utilization of large quantities of residues from the wood-using industries. Evaluation of the suitability of such raw materials requires information of the type presented in this paper.

Xylose in acidic solutions was reacted under isothermal conditions over a broad range of conditions of concentration, acidity, and temperature. The half-life of xylose under the conditions used ranged from 1 second to 5 hours. The yield of furfural increased with increasing sulfuric acid until the concentration reached 0.1 N. At higher acid concentrations, the rate of reaction increased in direct ratio to the acidity, but the maximum yield of furfural obtainable did not increase beyond that obtained for 0.1 N acid. Over the entire range of conditions used, increasing the temperature increased the yield, whereas increasing the xylose concentration decreased the yield, the decrease being greatest at low temperatures.

The results of this work show that favorable yields of furfural from pentose or pentosan-containing materials can be obtained by processing at high temperature in dilute solution without simultaneous removal of the product. A process based on such a technique would differ markedly from present commercial practice.

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Improving Wood's Durability

THROUGH CHEMICAL MODIFICATION[1]

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Wood preservation to date has been based on impregnating the wood with toxic chemicals. Future approaches may involve destroying vitamins or inactivating trace elements required by fungi.

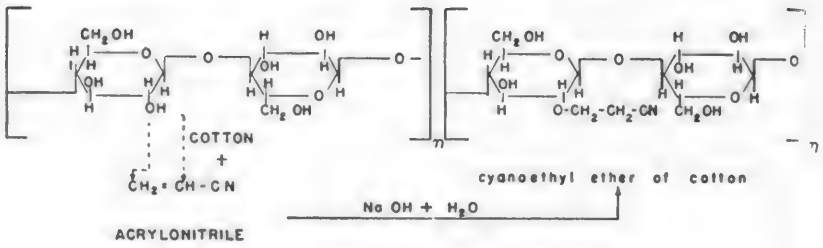

Fig. 1.—Reaction of acrylonitrile with cotton.

IT IS WELL KNOWN that the decay of wood is due to the action of living organisms called fungi. They use the wood as food by secreting enzymes that promote the dissolution of complex compounds of high molecular weight into relatively simple compounds. These compounds, being water-soluble, diffuse into the body of the organism and are utilized in its metabolism.

The role of fungi in the decay of wood was demonstrated by Hartig in 1874, a comparatively recent date with respect to the countless years during which wood has been used as a building material.

The tendency of wood to deteriorate under moist conditions was no doubt recognized in prehistoric times. This phenomenon was probably believed to be due to a softening effect of the water; accordingly the earliest efforts to preserve wood consisted of applying oily or tarry materials to exclude moisture. Some of these materials, notably coal-tar creosote, were toxic to the attacking organisms but this was not appreciated at that time.

After Hartig's classical studies, the emphasis of wood preservation experiments shifted from a search for water-excluding materials to a search for fungitoxic materials. This again illustrates the effect that a discovery in pure science may have on the direction of applied research. Some modern wood preservatives have certain virtues in addition to their toxicity toward wood-destroying organisms, but nevertheless it is essentially correct to say that modern wood preservation consists of impregnating wood with materials that are toxic to invading organisms. Furthermore, modern research on new materials for treating wood consists to a large extent of a search for improved toxics, especially for those that would lend themselves to the treatment of wood products with exacting requirements as to cleanliness, paintability, and freedom from odor. The logic of such research is apparent when one bears in mind the steady growth of the chemical industry, which shows no signs of decline in a virility that results each year in new compounds available to users of chemicals.

Chemical Modification of Cellulose

While the use of toxics dominates the theory and practice of modern wood preservation, considerable thought and a limited amount of experimentation has been devoted to several other means of preserving wood. Perhaps the most promising of these newer approaches consists of treating wood with chemicals that are not merely deposited in the wood, but undergo reactions with the cell wall substances. Some of the cellulose derivatives that are formed are not subject to dissolution by the enzymes of fungi.

The chemical modification of other forms of cellulose, especially cotton, has been studied intensively. Research on the chemical modification of wood such as that conducted by Stamm and coworkers has been aimed chiefly at reducing the tendency of wood to shrink and swell with changes moisture content. However, the possibility that wood so treated might be resistant to decay and insects has not been overlooked. Several promising leads have been uncovered.

Heating wood under conditions that just avoid charring induces chemical changes that make the wood decay resistant. The same result is obtained by treating the wood with formaldehyde gas in the presence of a catalyst. The acetylation of veneer not only reduces its tendency to shrink and swell with changes in moisture con-

WHAT THIS RESEARCH MEANS

The successful methods of wood preservation have been based on the impregnation of wood with chemicals that are toxic to fungi, insects, and marine organisms. Treatments based on other principles are being studied.

The chemical modification of cellulos so as to render it immune to dissolution by enzymes secreted by fungi offers a possible means of protecting wood against degradation by fungi. A number of such chemical reactions have been investigated. The cyanoethylation of wood is a promising reaction of this type. It consists of treating wood with an aqueous solution of acrylonitrile and an alkali and then heating the wood.

Another approach to the preservation of wood without impregnation with a toxic fungicide consists of treating the wood so as to destroy the thiamine present; this growth factor is required for the normal growth of practically all wood-destroying fungi. A third line of study consists of treating wood with chemicals that inactivate certain elements, trace amounts of which are required by fungi.

Editor

[1] Presented at Section V, Wood preservation, FPRS 12th National Meeting, June 22–27, 1958 Madison, Wis.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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tent, but also makes it resistant to decay and termites. Wood may be treated with a water-soluble, phenol-formaldehyde resinoid to form a decay-resistant product called impreg. For one reason or another, no practical application has been made of the above treatments where the preservative effect is the only one needed.

As a general rule, the chemical modification of wood is more costly than treatment with the preservatives that are now in commercial use. Some of the treatments that have been studied show an adverse effect on strength properties, especially toughness. However, a serious effect on strength is not a necessary feature of such treatment; furthermore an improvement in other properties than resistance to decay may be visualized. The fact that the treated wood is free from toxic chemicals would constitute an important advantage for some uses, and justifies experimentation along this line.

Cyanoethylation of Wood

During the past several years, experiments have been made at the Forest Products Laboratory on a method for the chemical modification of wood, called cyanoethylation. This reaction, which has been investigated thoroughly as a means of modifying cotton, is produced by a very reactive chemical called acrylonitrile acting on cellulose in the presence of an alkali.

In the cyanoethylation of cotton, the conditions may be varied to obtain different degrees of modification. Essentially, the cotton is first treated with a solution of sodium hydroxide and, after the excess solution is squeezed out, the wet cotton is mixed with acrylonitrile. The temperature is brought to 50° to 55° C. and held for approximately an hour. The various properties, including resistance to microbial attack, vary with the percentage of fixed nitrogen in the final product. Compton[3] and others, represents the reaction of acrylonitrile with cotton as shown in Fig. 1. Excellent resistance to microbial attack is shown by a product with 3.0 to 3.5 per cent fixed nitrogen. In this reaction, the sodium hydroxide functions as a catalyst and also serves to swell the cotton fiber, thus causing a more rapid pentration by the acrylonitrile.

In starting experiments on wood, it was accepted that the weakening effect of sodium hydroxide on wood rendered that chemical unsuitable as a catalyst. In addition to the relatively stable alpha cellulose, which is chemically similar to cotton, wood also contains up to 20 per cent hemicellulose, which has a higher alkali solubility than alpha cellulose. Weaker alkalis were therefore tried, with preference given to volatile alkaline compounds such as ammonia, which could be removed by evaporation after the desired chemical reaction between acrylonitrile and the cellulosic constituents of the cell wall had been obtained.

Another assumption was that a conversion of the cellulose molecules on or near the surfaces of the cell walls might be adequate for decay protection, even though the degree of treatment did not yield dimensional stability. It is known that the cellulose-splitting enzyme, cellulase, is not secreted by the fungus unless there is direct contact between the tips of hyphae and cellulose. By preventing this contact with a layer of modified cellulose, the secretion of cellulase might be prevented.

In the first experiments, ¾-inch pine sapwood blocks were impregnated with cold aqueous solutions containing different ratios of acrylonitrile and ammonia. The strongest solution contained 6 per cent acrylonitrile and 3 per cent ammonia. The treated blocks were placed on watch glasses and dried in heated air, some at 50° to 55° C. and some at 100° C. The blocks were then tested for decay resistance by the soil-block method. Three wood-destroying fungi were used, namely *Lentinus lepideus* (Madison 534), *Poria monticola* (Madison 698), and *Lenzites trabea* (Madison 617).

The blocks that were dried at 50° to 55° C. showed high weight losses after the decay-resistance test. Of the blocks dried at 100° C., some showed no weight loss. The results were erratic within different series so that the approximate level of treatment required could not be determined. It appeared that of the three fungi, *Lentinus lepideus* showed the least tendency to attack the treated blocks and *Lenzites trabea* the greatest. This was confirmed by later tests. In most subsequent tests, *Lenzites trabea* alone was used as the test organism in order to reduce the volume of work. It may be assumed to be the test organism unless otherwise stated in the remainder of this paper.

The variability of results within given series of blocks that was obtained in the first experiments was attributed to variations in the rate of loss of the two reagents from different blocks during drying. Acrylonitrile with a boiling point of 79° C. would of course evaporate more slowly than ammonia, but since both reagents are required for the reaction, the variable loss of ammonia alone would account for variations in results. In later experiments, the wet treated blocks were placed in jars, which were loosely capped during the heating stage. Fairly reproducible results were obtained in this way.

Factors Controlling Cyanoethylation of Wood

The main factors governing the rate of the reaction are believed to be: 1) concentration of acrylonitrile in the wood, 2) concentration of ammonia in the wood, 3) temperature, and 4) time. Detailed studies to establish the effects of these factors in relation to each other have not yet been made. The results obtained so far will be summarized to indicate in a general way the conditions needed to obtain resistance of sap pine blocks against *Lenzites trabea*. Retentions of chemicals will be expressed in terms used in commercial wood preservation, namely pounds of chemical per cubic foot of wood.

When blocks containing 0.95 pound acrylonitrile and 0.95 pound ammonia per cubic foot of wood were steamed 2 hours at a pressure of 15 pounds per square inch, complete decay resistance was obtained. Blocks treated to retentions of 0.62 pound acrylonitrile and 0.93 pound of ammonia per cubic foot showed a weight loss of 2 per cent after 12 weeks' exposure to *Lenzites trabea*. The same concentration of acrylonitrile with appreciably lower concentration of ammonia gave poor results.

It may be seen that the amount of acrylonitrile required is dependent to some extent upon the concentration of ammonia. Since the latter is by far the cheaper of the two chemicals, lowest chemical costs would seem to lie in the area of a high concentration of ammonia with a minimum concentration of acrylonitrile. The effect of a high concentration of ammonia on the strength of wood needs to be considered. More tests are needed to establish the most practical ratio of the two chemicals.

Since both reagents are volatile, some allowance for loss in handling might be needed in practical treatments.

A number of alkaline reagents other than ammonia have been tried. Disappointing results have been the rule with alkaline salts such as sodium carbonate, borax, and trisodium phosphate when used in the low concentrations believed to be only moderately harmful to wood. More promising results have been obtained with several or-

[3] Compton, Jack, Martin, W. H., Word, H. H. Jr., and Barber, R. P. Textile Res. J. No. 1:58–75.

ganic compounds that yield alkaline solutions in water, notably triethylamine and tetramethylguanidine. These compounds, being less volatile than ammonia, would seem to be more practical than ammonia if the heating stage were carried on in equipment other than a closed vessel.

The four different levels of temperature that have been tried were selected with a view to practical application rather than for the purpose of obtaining detailed basic information on this factor. The treated blocks were held at the following temperature: 1) room temperature, 2) 50° to 55° C., 3) 95° C.—a typical dry kiln temperature, and 4) 115° C.—a temperature commonly used in steaming green pine prior to treatment.

The most consistent results were obtained by steaming at 15 pounds per square inch (115° C.). Heating at 95° C. gave erratic results, and drying in air gave poor results with the chemical retentions mentioned above. The time of heating needed at any given temperature would no doubt vary with the thickness of the wood. No study has been made of this factor.

Chemical analyses of treated blocks showed that a modification corresponding to approximately 1 per cent by weight of fixed nitrogen is needed to prevent attack. Parallel analyses of untreated blocks showed 0.033 per cent fixed nitrogen. One series of blocks containing 0.88 per cent fixed nitrogen suffered very slight attack and a weight loss of 2 per cent.

Preliminary tests indicate that a similar level of treatment is needed to protect sap gum blocks against *Polyporus versicolor.*

The percentage of fixed nitrogen found in decay-resistant blocks is only about one fourth the theoretical amount corresponding to a complete conversion of the cellulose to the cyanoethyl ether of cellulose. Furthermore, it is considerably below the percentage found necessary to protect cotton from attack by micro-organisms. This could be explained by the assumption that only the surfaces of the cell walls of wood need to be chemically changed. Another explanation is that only the more reactive regions of the cellulose chains need be modified to prevent the initial attack by the fungus.

Acrylonitrile is known to undergo polymerization reactions, which might conceivably result in the depostion of toxic material in treated wood. To check this possibility, treated blocks that had been found to be decay resistant were ground into a fine powder, some of which was leached with hot water and some with alcohol. The aqueous extract when mixed with nutrient agar had no toxic effect on *Lenzites trabea.* The growth-retarding effect of the alcoholic extract was no greater than that of an equivalent amount of pure alcohol. These results show that the decay resistance is not due to the presence of toxic chemicals. They also point to a property that would be highly desirable under certain conditions. The freedom from extractable toxics would constitute an important advantage if the treated wood were to be used in contact with food or drinking water.

While ammonia has a much less drastic effect on the strength properties of wood than do the stronger alkalis, nevertheless some loss in strengh may be anticipated when wood that contains ammonia is heated. Further work is therefore indicated to find the conditions that will yield the desired modification of the cell wall with a minimum loss in strength.

Some exploratory experiments were made on the use of certain catalysts that have been found to be effective in the cyanoethylation of cotton. One, potassium iodide, showed a similar catalytic effect on the cyanoethylation of wood. Complete protection was obtained by air drying at room temperature 5 blocks treated to a retention of 1.17 pounds acrylonitrile plus 0.43 pound potassium iodide per cubic foot of wood. The use of a catalyst plus a mild alkali apparently makes it possible to obtain the desired reaction at ambient temperatures that would be advantageous in situations where facilities for heating the wood are not available.

The addition of this chemical makes possible a reduction in the concentration of ammonia, but with some increase in the total cost of chemicals. This increase in cost might be counterbalanced by a decrease in strength loss, but this assumption needs to be confirmed by strength tests on specimens treated with various formulations. The chemical cost of the treatment is more than doubled by the use of potassium iodide without an alkali; it would be several times the cost of any commercial treatment now in use. It seems doubtful whether this cost could be justified by other properties of the wood. More experiments along this line are planned with the aim of reducing cost. What is needed is a relatively low-cost catalyst that will promote the desired reaction to virtual completion before much acrylonitrile has been lost by evaporation.

Recent tests have indicated that the cyanoethylation of wood may be a reversible reaction so that, in the presence of large amounts of water, the ether linkage is hydrolyzed with the reformation of a hydroxyl group. Some blocks were given a treatment that had been found to import decay resistance. They were then impregnated with water and leached for several weeks. The leached blocks showed considerable decay when subjected to the standard test. Tests are in progress to determine whether a higher level of treatment will counteract the apparent susceptibility to hydrolysis.

Field tests have been started as a check on the permanence of the protection against decay under service conditions. Since some of the test specimens are exposed in a plot in which termites are active, the resistance of the treated wood to termites will also be determined.

Tests made up to the present time indicate that the level of treatment that is adequate to impart decay resistance has no significant effect on dimensional stabilization.

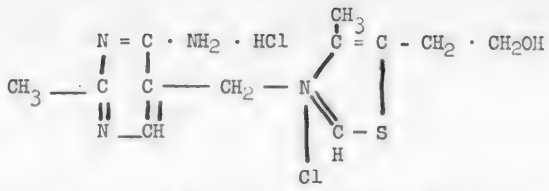
Though, as has been mentioned work is in progress to determine more accurately the optimum conditions for obtaining decay resistance with a minimum effect on the strength properties of the wood, it is planned also to investigate other properties of the treated wood such as resistance to mild acids and resistance to moderately high temperatures. Experiments are also planned on applying the two chemicals in the vapor phase.

Modification of Minor Constituents of Wood

Destruction of Thiamine in Wood: Cellulose being the major component of wood as well as the major item in the diet of fungi, it is natural that efforts to modify wood chemically to obtain decay resistance start with reactions involving cellulose. However, the very fact the cellulose is present in such large amounts makes it necessary to use moderately large amounts of chemical to obtain any effective degree of modification. Prospects for obtaining decay resistance with very low chemical consumption appear much brighter when one contemplates chemical transformation of the minor constitutents of wood that are essential to the metabolism of fungi.

The growth factor thiamine (Vitamin B_1) is an outstanding example of a compound that is naturally present in wood in trace amounts and is required by wood-destroying fungi. Kogl and Fries[4] found that most wood-rotting fungi can utilize inorganic form of nitrogen only when also supplied with a small amount of thiamin

[4] Kogl, F., and Fries, N. 1937. Hoppe Zeyl Z., 249:93–110.



Thiamine chloride hydrochloride. Destruction of minor wood elements such as this, which are essential to metabolism of fungi, could make fungal growth impossible.

Fries[5], in studying the nutritional requirements of 12 fungi, found that thiamine stimulated the growth of all. Five exhibited an absolute demand for thiamine. *Lenzites* saepiaria grew very feebly without it. Filtrates of cultures of bacteria insolated from wood stimulated these fungi, which indicates that the bacteria are able to synthesize thiamine. Noecker[6] mentioned four wood-destroying fungi that require thiamine. Jennison[7] and others, using submerged culture (shake) in synthetic media, studied the growth and nutrition of 42 species of Basidiomycetes, including both brown rots and white rots. They reported that "two species of the 42 had no vitamin requirements; most of the others were deficient only for thiamine. . . . two had vitamin requirements in addition to thiamine."

These facts lead one to the assumption that wood treated to destroy its thiamine content would be nonvulnerable to attack by most fungi so long as outside sources of thiamine were excluded. Outside sources of thiamine are numerous. Because of its intimate relation to carbohydrate metabolism, thiamine plays an important role in the life of plants and micro-organisms. It is therefore widely distributed throughout the vegetable kingdom. Plants seem able to synthesize enough for their own needs. Although many micro-organisms are able to synthesize it, others will not grow unless it is supplied to them. It is difficult to visualize an absence of thiamine on the surface of wood exposed to any soil that will support vegetation. Even when wood is used out of contact with the ground, one must recognize sources of thiamine in the form of surface molds, air-borne spores, organic dust, washings from overhanging trees, and others. It should not be accepted without proof, however, that such sources of thiamine would in most cases be adequate to support decay organisms appreciably. Furthermore, some wood products are partially portected under normal conditions from the contaminants mentioned. Others, such as structural members of buildings, may be well protected. In many situations, a paint film might exclude thiamine from the underlying wood. It seemed desirable, therefore, to conduct some experiments aimed at imparting decay resistance to wood by the destruction of its thiamine content.

The chemical nature of thiamine is fairly well understood. The accepted structure of thiamine hydrochloride is shown at the beginning of this article.

The stability of thiamine is dependent largely upon pH. At a pH below 7, it is quite stable, which accounts for its negilible loss from some foods on cooking. It is less stable in neutral solution, and its rate of decomposition on heating increases with pH. Farrer[8] found that, at a temperature of 100° C. and a pH of 7, thiamine was 96 per cent destroyed in 2 hours; at pH of 8 it was 100 per cent destroyed in 1 hour; at a pH of 9 it was 100 per cent destroyed in 15 minutes.

It was recognized that only tests under actual use conditions would yield conclusive evidence of the service life of wood treated to destroy the thiamine. Preliminary laboratory tests were undertaken mainly to get some idea of the intensity of conditions needed to cause an apparent destruction of thiamine in wood. Experimental difficulties encountered in these tests have not as yet been completely solved.

One requirement is to hold the test block within a favorable moisture range without contact with soil, agar, or other materials that might constitute a source of thiamine. Placing the treated moistened block on a glass triangle over a layer of nutrient-free, low-thiamine agar has proven fairly satisfactory.

The inoculation of the block presents another problem. The object is to infect the block with an inoculum that is very low in thiamine, but sufficiently virile to attack without fail an untreated control block. Growing the fungus cultures on synthetic media that is low in thiamine has proven fairly satisfactory.

The medium used to grow cultures for these tests was patterned after the formula given by Jennison and coworkers. The formula used was as follows:

Noble special agar	15.0 grams
Glucose	10.0 grams
l-Asparagin	0.57 gram
KH_2PO_4	1.5 grams
$MgSO_4 \cdot 7H_2O$	0.50 gram

Trace elements: B, 0.10 mg.; Cu., 0.01 mg.; Fe, 0.05 mg.; Mn, 0.01 mg.; Mo, 0.01 mg.; Zn, 0.07 mg.
Distilled water to make 1 liter

Agar plates were poured from this medium, and the initial transfers were made from a culture growing on malt agar. The ability of four test organisms to grow with repeated transfers on the synthetic medium varied greatly. *Lenzites trabea* could be transferred from synthetic medium to synthetic medium with apparently little loss of vigor after 4 or 5 transfers. *Poria monticola*, on the other hand, grew on synthetic medium only when the inoculum was taken from a malt agar culture. *Polyporus versicolor* grew vigorously on the first transfer to synthetic medium but very feebly on the second. *Lentinus lepideus* showed a similar tendency. Whether these differences reflect the abilities of the organisms to conserve thiamine or whether they stem from differences in minimum requirements has not been ascertained. *Lenzites trabea* and sap pine blocks have been used in most of the tests. A few tests on pine have included *Lentinus lepideus* and *Poria monticola*. Some tests have included gum blocks with *Polyporus versicolor* as the test organism.

By the use of such cultures, fairly consistent results have been obtained in most series of tests, but the reproducibility of the method does not equal that of the soil-block test. Occasionally, for example, an individual untreated control block may remain free from decay when other blocks in the same series show profound decay. In a set of five treated blocks, it is common for one of the blocks to behave differently from the other four. The results of such experiments can be accepted only with some reservation.

The loss in weight that untreated blocks undergo in 12 weeks of exposure under these test conditions is less than is shown by untreated controls tested by the soil-block method. Blocks inoculated with *Lenzites trabea* lose in the neighborhood of 30 to 35 per cent of their initial weight in 12 weeks, as compared with a typical weight loss of 50 to 60 per cent in the soil-block test.

Types of Chemicals Used Experimentally

A number of chemicals, both volatile and nonvolatile, that yield an alkaline

[5] Fries, N. 1938. Symb. Bot. Upsaliens 3:81.
[6] Noecker, N. L. 1938. Amer. J. Bot., 25:345.
[7] Jennison, M. W., Newcomb, M. D., and Henderson, R. 1955. Mycologia 47, No. 3:275–04.
[8] Farrer, K. T. H. 1941. J. Proc. Austral. Chem. Inst. 8:113.

solution in water have been tried. The Application of volatile chemicals during kiln drying has been visualized, but up to the present time, most treatments with such chemicals have been made by impregnating weighed blocks with aqueous solutions of known strength. In this way it is easy to determine the amount of chemical absorbed by the wood and thus calculate the chemical cost of the treatment.

Ammonia, a volatile compound, and triethyl amine, which boils at 89° C., were used under several sets of conditions. Ammonia did not impart decay resistance if allowed to evaporate from treated blocks at room temperature. If the treated blocks (sap pine or sap gum) were held in loosely covered jars and steamed for 2 hours at a pressure of 15 pounds per square inch, or heated in an oven at 95° C., they showed decay resistance by the test method described. The amount of ammonia required was of the order of 0.15 pound of NH_3 per cubic foot of wood when the blocks were steamed after treatment. The results are more erratic when the blocks were oven-heated, and it seems somewhat higher retention of chemical is necessary. The difference may lie in the ratio between rate of decomposition of thiamine and rate of loss of ammonia.

The addition of chlorine to the solution of ammonia appeared to increase its effectiveness. Hydrogen peroxide was less effective as an additive.

A number of tests have been made on triethylamine, and preliminary tests have been made on other organic compounds such as monoethanolamine, triethanolamine, tetramethyl guanadin triethanolamine, tetramethyl guanadine, pyridine, quinoline, and dimethylformamide. The results have varied somewhat, but appear to be related to the pH of the aqueous solution.

With the less volatile compounds, a decrease in the rate of decay, and occasionally a complete freedom from decay, may be obtained by allowing the treated blocks to dry at room temperature. More positive results are obtained by heating the treated blocks. For example, a retention of 0.1 pound triethylamine per cubic foot was effective when the treated blocks were steamed, but a retention of four times that amount did not prevent decay of some blocks that were dried at room temperature. A retention of 0.1 pound per cubic foot of monoethanolamine with steaming was effective, but a retention of 0.6 pound per cubic foot without steaming was ineffective.

Several inorganic salts were tried. Dilute trisodium phosphate treatment followed by air drying seemed to be effective; the addition of a low concentration of chlorine increased the effectiveness of dilute solutions. Neither sodium chromate nor sodium dichromate were effective in retentions of the order of 0.1 pound per cubic foot.

Inconclusive results were obtained in several repeated experiments in which a dilute solution of thiamine was added to blocks that had been treated to destroy their naturally occurring thiamine. Such blocks as a rule were attacked by the fungi, but the rate of growth was much slower than on untreated controls. Apparently the heating of blocks containing an alkaline solution induces changes unfavorable to the fungi in addition to the destruction of thiamine.

It is emphasized that the foregoing results are of a preliminary nature. Efforts are being continued to improve the laboratory technique for studying this type of treatment, and the exploratory tests described are being followed by more detailed experiments.

A small number of treated specimens have been placed in service tests involving both ground-contact and above-ground exposures.

Inactivation of Trace Elements

The nutritional requirements of fungi have been studied by many investigators, and it is beyond the scope of this paper to attempt to review their work. The major elements required are: carbon, nitrogen, phosphorus, potassium, magnesium, and sulfur. The synthetic medium used successfully by Jennison and coworkers contained the following minor elements (listed in the order of their atomic numbers): molybdenum, zinc, copper, iron, manganese, and boron. The role of these indispensable trace elements in the nutrition of fungi is obscure. In view of the small quantities required, their function is quite likely of a catalytic nature. Enzymes containing these elements have been identified in plants and animals.

The possibility of preventing the growth of fungi in wood by rendering the trace elements unavailable is attractive mainly because it conceivably might be accomplished with a small amount of the reacting chemicals. As with the destruction of thiamine, it seems possible that the inactivation of trace elements might be accomplished by a vapor-phase treatment in conjunction with kiln drying. The idea, on the other hand, has a discouraging aspect insofar as the use of treated wood in soil contact is concerned. It seems likely that most soil would constitute a reservoir of trace elements. Like a treatment designed to destroy thiamine, a fugitive treatment designed to inactivate trace elements seems unlikely to be successful unless the treated wood is used out of contact with the soil and also shielded from gross contamination with any matter that might contain the trace elements. A more or less permanent chemical capable of inactivating trace elements should impart more lasting protection, similar to that afforded by a relatively permanent toxic.

The simplest type of reaction that comes to mind is the formation of sparingly soluble compounds of the trace elements by well-known double decomposition reactions. For example the hydroxides of the trace metals might be formed by the addition of ammonia. The hydroxides of these metals are designated as insoluble, but they do dissolve to a slight extent. This slight solubility of these hydroxides might be sufficient to provide fungi with their extremely small requirements of the trace metals.

Another type of chemical change that may be visualized consists of the formation of extremely insoluble compounds by causing a reaction between the trace elements and some of the more reactive constituents of wood under the influence of a modified pH or a modified redox potential. The former condition could be produced by the addition of acids or alkalis, while the latter could be produced by oxidizing or reducing agents.

Conditions that are severe enough to lead to reactions of the type just mentioned might also lead to a destruction of thiamine. Furthermore, they might produce changes in compounds, like the carbohydrates of low molecular weight, that may be necessary for the initial attack by the organism. It is obvious that carefully designed and involved experiments are needed to clarify the over-all effect produced by such treatment.

Use of Chelating Agents

Of the different types of reaction that might be utilized, chelation appears promising. Chelation is a general type of reaction between metal ions and certain organic compounds whereby the metal ion is incorporated into the organic molecule, and is thus inactivated chemically. Metals vary in their tendency to form chelates, and different chelates vary in their stability. Some decompose when heated.

Some chelated compounds have been found to be suitable sources of the element for growing plants. Others are not utilized by certain micro-organisms. There appears to be no published information on the ability of wood-destroying fungi to utilize chelate forms of trace elements.

There has been a considerable amount of research devoted to the use of chelating agents to prevent microbial attack of various materials such as textiles. A chelated compound called copper-8-quinolinolate has been found to be a very effective microcide. Its principal use has been in the treatment of textiles for military use, but it is also being applied as a dip to certain specialty wood products such as baskets and crates for picking and transporting vegetables. The small amount of chemical required to prevent the growth of fungi has led to the theory that its action involves some effect on the enzyme system of the organisms.

One may visualize several ways in which a chelation reaction might serve to prevent the decay of wood. In the first place a more or less permanent chelating agent deposited in the wood might inactivate the enzymes of fungi by forming chelates with the metals present in the enzymes, and thus give lasting protection to the wood. Broadly speaking, such chemical could be classed as a toxic since its effect would depend upon a chemical reaction with a constituent of living protoplasm. A permanent chelating agent might also react with minor metals present in the wood either naturally or through diffusion from surrounding soil. Since the fungus would be deprived of a source of these essential metals, the synthesis of enzymes and therefore the growth of the fungus would be prevented. Another theoretical possibility would be the chelation of the minor metals in uninfected wood by means of a fugitive chelating agent, for example, a low-boiling liquid introduced into a kiln during the drying of lumber. Any preservative effect obtained in this way could not be regarded as due to a toxic chemical, since it would involve no reaction between a chemical and living protoplasm. It could be expected that wood so treated would be immune to decay only so long as the access of essential elements was prevented.

Exploratory experiments along this line are in progress at the Forest Products Laboratory. Protection against decay has been obtained by treating pine blocks with a chelating agent and exposing them to essentially the same test conditions as were used in experiments on the inactivation of thiamine. Of the minor elements that are essential to fungi, copper, zinc, manganese, and magnesium are chelated by ethylene diaminetetraacetic acid (EDTA) under alkaline conditions. Since the optimum pH varies for each element, much work would be needed to determine the most favorable range of pH. Ferric iron is not chelated above a neutral pH.

In the first series of experiments, the chelating agent was a water solution of an alkaline salt of EDTA. Varied amounts of alkali were added to the treating solutions; the maximum pH used was 12.2. Some of the treated blocks were dried at room temperature without heating, while others were steamed for 2 hours at a temperature of 155° C.

When ammonia was used as the alkali and the blocks were not heated, no attention was paid to residual alkalinity. It has been found that such treatment alone does not impart immunity to decay under the test conditions used. When sodium hydroxide or trisodium phosphate were used, the treated blocks were leached with distilled water before being exposed to the fungus. Leaching was continued until the leach water was practically neutral.

Protection against decay was obtained with an initial retention of 0.09 pound EDTA plus 0.06 pound ammonia per cubic foot of wood. Retentions of half this amount gave inconclusive results; some blocks showed moderate decay while others showed no decay.

It is difficult to establish the exact mechanism of the protection against decay that is caused by the treatment described. The low toxicity of the chemical in the agar-flask test indicates that the effect is not a toxic one. The chelation of certain minor metals seems like a plausible explanation, but other reactions may be contributing to the immunity to decay.

Further tests are underway on the treatment described and also on several other chelating agents. It is hoped that a better understanding of the changes taking place in the wood will be developed.

Discussion

I. S. Goldstein (Koppers Co.): It was noted in the slide showing the cyanoethylated soil block that fungi did not grow over the block. It has been our experience in some instances that even when fungi did grow over such a block that there was no weight loss. Does this have any significance?

Dr. Baechler: Fungi are very different in this respect. Some will grow over a block only when they attack it; others will cover a block without attacking it. Such fungi will cover an inert object such as a marble.

E. A. Behr (Chapman Chemical Co.): Have you tested preferential fungi to see if either cellulose-preferring or lignin-preferring fungi attacked the treated blocks differently?

Dr. Baechler: No, we have not.

A. S. Gregory (Weyerhaeuser Timber Co.): When you have 90% efficiency of cyanoethylation of wood and 0.9% N_2 combined, how deep is the treatment estimated to be?

Dr. Baechler: We have made no measurements of depth of treatment. However, there is probably a heavier treatment on the outside.

Dr. Gregory: When you use NH_3, is this stepwise followed by acrylonitrile? If so, could you describe the conditions?

Dr. Baechler: The procedure is to add both chemicals in water to form a mixed solution. The wood is first treated with a cold solution, and the temperature is then raised.

Mr. Schwartz: There are techniques for acetylation that do not cause loss of strength, are there not?

Dr. Baechler: Yes, there are.

E. B. Cowling (U.S. Forest Products Lab): Can you indicate properties needed in a chemical in order that it may react with cellulose?

Dr. Baechler: It is difficult to generalize on this point. A number of different reactions are possible; for example, esters or ethers may be formed. Different types of chemicals will produce these reactions. Merely heating the wood at controlled temperatures will cause the formation of linkages.

John Talbott (Washington State Institute of Technology): Would the method of destroying thiamine by heat at high pH be applicable to particle board through action of the press temperature on a mix containing al alkaline resin solution?

Dr. Baechler: We have visualized this phenomenon, but have not tested for it.

R. C. Sproull (Phillip Morris, Inc.): Are reprints of these data available?

Dr. Baechler: No, the work is not yet completed, but they will be published when the work is done.

Dr. Sproull: What has been done to produce permanent fire resistance by permanent chemical changes in the wood, such as reacting the OH groups with chemical agents to produce permanent changes?

Dr. Baechler: I don't know how much has been done along that line. We have discussed it at the Laboratory, but have not gone beyond a few simple tests.

Mr. Sayward: In the chemical modification of wood (presumably principally on the surface) will not an avenue of attack be opened as soon as the wood is cut to build products, or even if the surface is damaged?

Dr. Baechler: Not necessarily. While we visualize the effect of mild treatments as being confined to the outer parts of the fibrils, it is not confined to the outer part of a piece of wood.

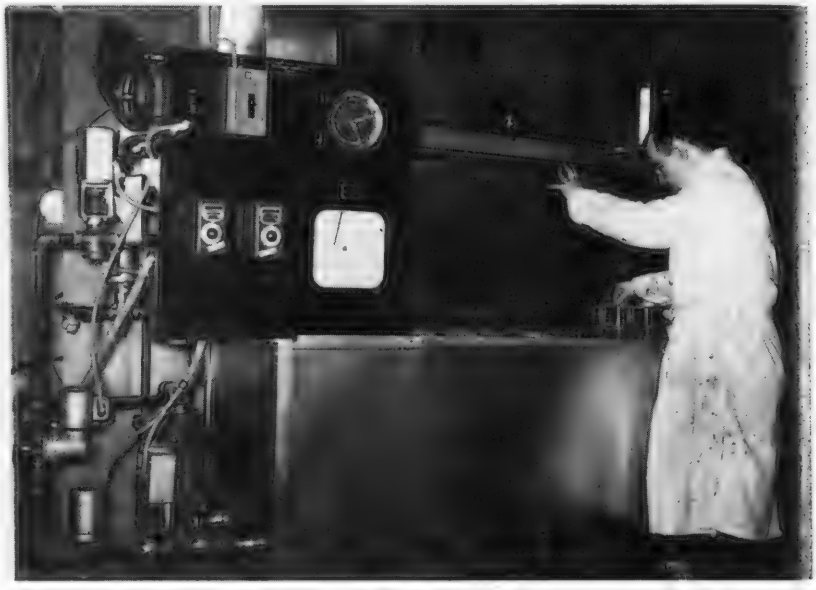
INDUSTRIAL USES OF AN

Automatic Machine for Glue Bond Testing[1]

B. S. Bryant, J. D. Blanchard, and O. F. Campbell, Jr.

University of Washington College of Forestry, Seattle

A fully automatic, rapid-cycle delamination test machine developed by the authors is sensitive to the variables that affect glue bond quality. With this machine, plywood not now covered by Commercial Standards can be evaluated.



One of the authors removes a group of specimens for a delamination check midway in the test cycle.

THE AUTOMATIC DELAMINATION ng machine developed at the University of Washington College of Forestry resulted from two distinct efforts to solve related problems. The object of these efforts was to develop a rapid and sensitive means of evaluating the glue-bond quality of non-standard softwood plywood for use in glue development work, as well as for use by the plywood manufacturer in quality control. A rapid and convenient test would permit the manufacturer to determine and reduce his per cent defective, the ultimate objective being the possibility of the manufacturer's issuing certificates of quality on individual shipments if desired. It was deemed advisable to adapt the test to a sampling procedure that does not require destruction of the panel.

The April, 1958 issue of the FOREST PRODUCTS JOURNAL, which featured veneer and plywood, contained a complete discussion of the work done by Oliver F. Campbell Jr. at the University of Washington College of Forestry. His work established the validity of a modified delamination test which involved the use of an automatic cycling machine. Hence it is not necessary that the details of this development be reiterated. It is interesting to note, however, that the same issue of the FOREST PRODUCTS JOURNAL presents work of Dr. Hart of North Carolina State College of Forestry on the development of a rapid delamination test for hardwood plywood that could be made automatic.

Currently, also, the Canadian Forest Products Laboratory at Vancouver, British Columbia is developing an automatic testing machine for plywood specimens. It appears that the need for a fast, reproducible test for the evaluation of certain types of plywood is well recognized, and that the realizing of this need by glue-development laboratories for glue evaluation studies and by manufacturing plants for plant-level quality control is overdue.

The purpose of this paper is to show how the validity of the rapid-cycle delamination test was established for a non-standard type of plywood, how the test is being applied in the industry today, and how recent experimental evidence indicates the future possibilities of extending this type of test to lumber laminates and other glued products.

Use of the Delamination Test for Evaluating White-Speck Plywood

A cooperative research project was set up between the University of Washington and the Edward Hines Lumber Co. in January, 1956 to develop a suitable method of evaluating exterior-type white-speck plywood. Several criteria were established that any proposed test had to meet: (1) the ability to evaluate accurately glue bond quality in exterior white-speck plywood; (2) approximation of actual use conditions; (3) rapidity of the testing method; (4) simplicity. The type of test that would most nearly meet these conditions would be a severe delamination test.

Since exterior white-speck plywood was to be tested, a variation of the cy-

[1] Presented at Session VIII, Glues and Gluing, FPRS 12th National Meeting, June 22–27, 195 Madison, Wis.

The Authors: Ben Bryant, Assistant Profess of forest products, holds an MS from the Un versity of Washington and a DF from Yale. H has been on the faculty since 1950.

Jack Blanchard graduated in wood technolo from the University of Washington, and di research on utilization of white-speck plywoo sponsored by Edw. Hines Lumber Co. He is nov with the technical service lab, American-Mariett Co., Seattle.

Oliver Campbell holds a BS from Iowa Stat and anMF from the U. of Washington. Up graduation, he joined the research and develop ment division of U.S. Plywood, Seattle.

clic delamination test developed by Haigh[2] was adopted. A cycle consisting of 2-hour vacuum soaking period, a 2-hour atmospheric pressure soaking period, and a 20-hour drying period at 145°F. was used to produce severe testing conditions. To fit into a small, laboratory vacuum chamber, a specimen 8 inches long by 2 inches wide was used. The testing cycle was repeated as many times as necessary to produce some glue-line delamination in most of the specimens. Preliminary work showed this cycle and specimen size would produce measurable edge delamination in exterior Douglas-fir plywood after 4 or 5 cycles.

To test the sensitivity of the proposed delamination test for exterior white-speck plywood, an experiment was conducted, the design of which is illustrated in Fig. 1. The three adhesives used were two exterior-type bark-flour-extended phenolic glues of the type used by Edward Hines Lumber Co. (glues A & B) and a furafil-extended phenolic glue of a type commonly used for Douglas-fir plywood (glue C). The white-speck grades recognized were the same as are used by the Edward Hines Lumber Co.

Class I white-speck
Class II white-speck
Class III white-speck

The three assembly times—3, 15, and 60 minutes—and the two press times—normal and ½-minute short—were selected to produce a range of panel quality.

Each of the 54 panels from this experiment were evaluated by the standard test for exterior plywood (per cent wood failure), and closely matched specimens were evaluated by the proposed cyclic delamination test. The results of this experiment are shown in Fig. 2.

It will be noted that tests by both criteria reveal that the individual glues show dissimilar curves over the range of assembly time used. For example, in veneer class combination I & III, one of the glues shows a general falling off of performance with increasing assembly time, while the other two reach an optimum at 15 minutes and give poorer bonds at shorter and longer assembly times. However, the relative position of these three curves is not the same in each combination of veneer class for either of the two criteria of testing.

This three-way inter-relationship between the effect of glue, assembly time, and the combination of white-speck veneer class appeared as significant in the interpretation of both tests by

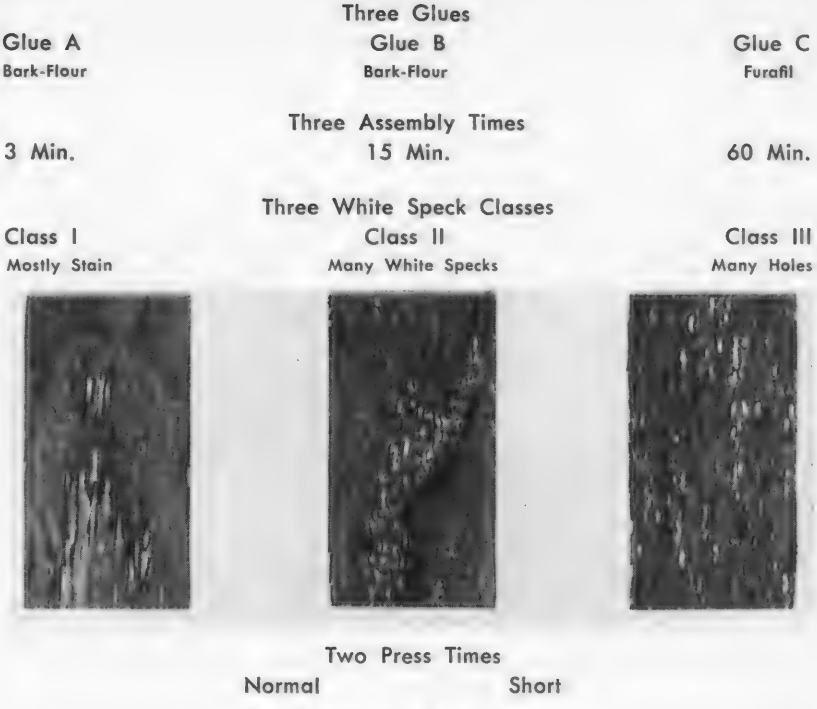


Fig. 1.—Design of the experiment.

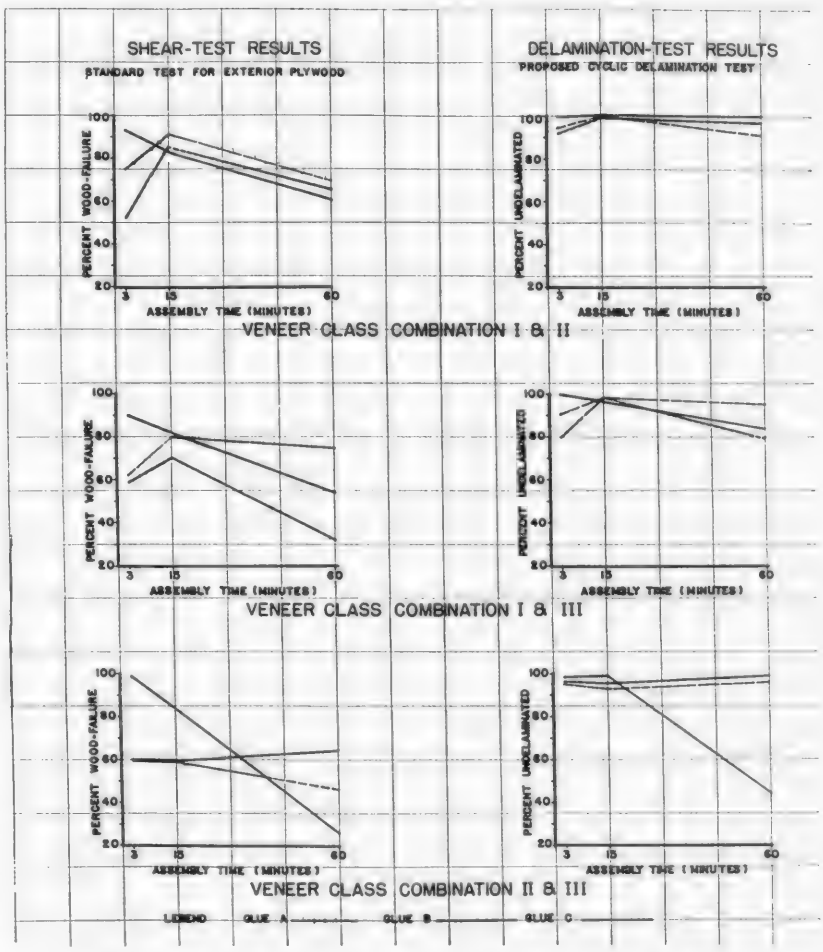


Fig. 2.—Comparison of two methods of evaluating white-speck plywood.

[2] Haigh, H. W. 1955. Evaluating Interior Plywood. Forest Prod. J. V(5):285.

means of statistical methods. The basic question is: Which of the two criteria best represents the anticipated performance quality of the plywood? The authors of the work summarized in this illustration concluded that: (a) since the delamination test proved to be less sensitive to those surface characteristics of white-speck veneer that affect the estimation of per cent wood failure, (b) since the delamination test proved to be equally sensitive to gluing conditions that are known to influence glue-bond quality, and (c) since the accelerated delamination test unquestionably is related to long-time resistance to delamination of plywood in service; therefore, the delamination test is a valid method of evaluating exterior white-speck plywood.[3] With reference to the illustration, the authors concluded that white-speck plywood made with all three glues and all three veneer class combinations at 15-minute assembly time will show equal resistance to delamination in service as indicated by the delamination test. White-speck plywood will not decrease in expected performance, as indicated by the wood-failure criterion, when the grade combination of veneer contains more pockets and when gluing conditions ordinarily would be optimum.

Establishing the Validity of the Delamination Test for Hardwood-Faced Plywood

This portion of the paper will deal with the original work of developing the delamination machine as a method of detecting poor glue bonds. This work is presented in detail in the April 1958 issue of the FOREST PRODUCTS JOURNAL. The picture of the original pilot model shows the basic form of the machine.

The purpose of the machine was to determine the feasibility of detecting interior-type glue bonds of inferior quality in hardwood-faced softwood plywood. The machine is basically a device to soak and dry rapidly the plywood in a short period of time, automatically. The cycle used is an accelerated one to obtain an index of service conditions in a short period of time. A designed experiment was used to select the optimum cycle of several tried. Specimens were soaked at room temperature and dried at a temperature of 145° F. A time clock controls the functions of the component parts of the machine. In this way, a large number of samples may be tested in a relatively short period of time compared to the present 10-cycle test, and the proposed method is not inhibited by an 8-hour working day.

Preliminary work on the machine, with ¾-inch Douglas-fir panels, was based on the assumption that the cycle selected for automation was as sensitive to poor glue bonds as was the Commercial Standard test for interior plywood (C.S. 45–55), and other accelerated types of delamination tests.

The next logical step was to compare the delamination machine test with other methods of glue-bond evaluation. The delamination machine test method was compared with wood failure, shear strength, and Northcott's cleavage strength tests. The experiment included five factors:

- Core species (Douglas-fir and mahogany)
- Type of face stock (rotary and sliced Philippine mahogany)
- Density of face stock (low and medium)
- Type of glue (extended phenolic and urea)
- Assembly time (optimum and extended)

The wood-failure method was sensitive to all these five main factors, while the delamination machine test method was sensitive only to glues and assembly times. This specific sensitivity to the two factors directly related to glue-bond quality emphasizes the advantage of the delamination machine. Strength tests, on the other hand, were not sensitive to any of the five main factors.

Use of the Delamination Testing Machine in the Adhesive Development Laboratory

The automatic delamination machine built for the American–Marietta Co. is similar to the original machine developed at the University of Washington, but is of a larger size. This machine is built with electric heaters for the drying cycle since steam is not available at all times. The capacity of the machine is 243 specimens, which are arranged in the special racks.

The testing cycle can be adjusted to any combination of soaking and drying. At present, a 4-hour soaking period and a 4-hour drying period at 150° F. is being used. The testing period is for 10 cycles, which takes 3⅓ days to complete. The specimens are 1 inch wide and either 8 or 10 inches long, with the face grain parallel to the long dimension. The specimen size (2 x 6 inches) proposed by the Douglas Fir Plywood Association can also be used in the racks.

At the present time, the American–Marietta Co. is using the automatic delamination machine to evaluate experimental plywood panels. The glues are primarily interior-type protein glues as used in the West Coast plywood industry.

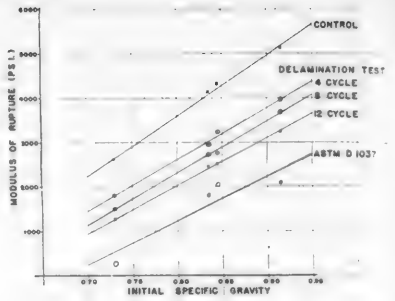


Fig. 3. Modulus of rupture test results on phenolic-resin-bonded particle board after accelerated aging.

After the completion of the testing period, the total delamination on the specimen glue lines is measured with a map measuring instrument. This device indicates cumulatively the number of inches of delamination. The total glue line delamination is recorded and the per cent delamination is calculated.

The automatic delamination machine has been used to evaluate bonded materials other than Douglas-fir plywood, principally hardwood-faced plywood. The particle board tested contained a phenolic resin binder to give greater durability. Samples of three specific gravity levels were cycled in the machine for 4, 8, and 12 cycles and then tested for modulus of rupture. The results obtained (Fig. 3) were lower than on the control samples, but not so low as when the ASTM accelerated aging test (ASTM D1037) was used prior to determining the modulus of rupture. One might anticipate, however, that a greater number of cycles would eliminate this discrepancy. It appears that the cyclic delamination machine could be used as an alternate —and simpler—accelerated aging test for particle board.

The authomatic delamination machine has proven to be a very useful tool in evaluating the glue-line quality of experimental laboratory panels glued with interior-type glues. The delamination test is rapid, severe, and simple to use. The values obtained from this test reinforce the values obtained from the standard tests for interior plywood, but the outstanding difference, brought out by Haigh, is that the results are better adapted to statistical treatment than are results from the standard test.

Future plans for this machine will include: (1) shortening the cycle to speed up the test results, (2) adapting the delamination test to evalua

[3] Bryant, B. S., H. D. Erickson, J. D. Blanchard. 1958. Glue Line Evaluation Technique for White-Speck Douglas-Fir Plywood. Bulletin, College of Forestry U. of Washington, Seattle.

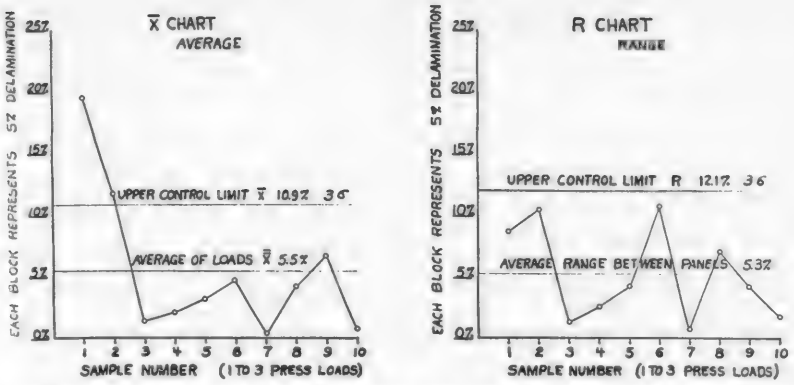

X CHART
AVERAGE
EACH BLOCK REPRESENTS 5% DELAMINATION
UPPER CONTROL LIMIT X̄ 10.9% 3σ
AVERAGE OF LOADS X̄ 5.5%
SAMPLE NUMBER (1 TO 3 PRESS LOADS)
R CHART
RANGE
EACH BLOCK REPRESENTS 5% DELAMINATION
UPPER CONTROL LIMIT R 12.1% 3σ
AVERAGE RANGE BETWEEN PANELS 5.3%
SAMPLE NUMBER (1 TO 3 PRESS LOADS)

Fig. 4.—Delamination machine results; interior glue after 24 hours consisting of 6 cycles of 1-hour soak at 70° F. followed by 3-hour dry at 145° F. (1) Delamination read on trim edge next to panel. (2) Subgroup size = 3 panels. (3) Delamination expressed as per cent of glue line exposed.

exterior-type laboratory panels, (3) using the machine as an accelerated aging test for particle board, and, of course, (4) for evaluating interior-type glue bonds.

Use of the Delamination Testing Machine in the Plywood Plant

A production-size delamination testing machine was constructed for U. S. Plywood's Seattle mill. The present cycle permits completion of 6 cycles in a 24-hour period. The specimens reach a moisture content above fiber saturation point in a 1-hour soaking period, and are dried to approximately 5 per cent (oven-dry basis) by the end of the 3-hour drying period. This model machine holds approximately 850 one-by ten-inch specimens. Heat is furnished by steam to control the temperature of the water for soaking and of the air for drying. Basically the same cyclic treatment is given the plywood as in the original machine, but now the machine operates with greater control because of more sensitive thermostats, time clock and recorder, and a more adequate air distribution system.

Sampling of production plywood is accomplished from the trim on the 8-foot length of the panel. This is the realization of one of the original purposes of the test, that is, to permit non-destructive testing of panels. Delamination is read only on the trim edge next to the panel. The assumption involved in sampling the trim is that the edge (opposite from spreader) is probably the poorest glue bond area of the panel, except for blows or blisters. If this area is of acceptable quality, the rest of the panel should be as good or better. The influence of assembly time and precure will be greatest on the edges of the panel layup.

Trim is sampled in a stratified manner along the panel. The average delamination per load (three panels per load) is determined and plotted on a Quality Control Chart of the Average (Fig.4). The range between the delaminations which represented the individual panels is plotted on the Range chart.

On this example of an X and R chart, it is observed that samples 1 and 2 are out of control on the Average chart. All the samples were within control on the Range chart, however. The conclusions regarding samples 1 and 2 are that the sample results showed the complete load to be of inferior quality compared to the rest of the samples.

The use of the delamination machine in production quality-control testing is in its infancy, and the hope for the future is that defective interior plywood, with regard to the glue-line quality, will be minimized by the use of the machine. It is also anticipated that greater process control and improvement in service to the customer can be performed.

Application of Automatic Cycling to Lumber Laminates

Since the advantages of automatic cycling were obvious, it was of interest to determine the feasibility of using the machine to apply rapid delamination cycles to lumber laminates. An undergraduate research project was designed and executed to investigate this possibility at the College of Forestry[4]. The primary purpose of the study was to determine whether the delamination results would be sensitive both to inherent and to built-in differences in glue-line quality, and to delamination stresses brought about by varying the levels of some important gluing variables. If such sensitivity could be demonstrated, the test and the machine might be attractive to the laminating industry as a convenient quality control tool.

The following variables and levels were used:

Glue type: Commercial phenol-resorcinol (A), an experimental laminating glue (B)
Assembly time: 10 minutes, 50 minutes, and 90 minutes
Species: Douglas-fir and white oak
Specimen size along the grain: 1 inch and 3 inches.

Other important variables were controlled within the anticipated optimum range for a room-temperature laminating procedure of this type.

The number of cycles completed, divided by the end-grain delamination expressed as a per cent of the glue line exposed at the ends of the specimen, gave a measure of glue-line efficiency. This was called Relative Glue Bond Efficiency. Accordingly, if after one

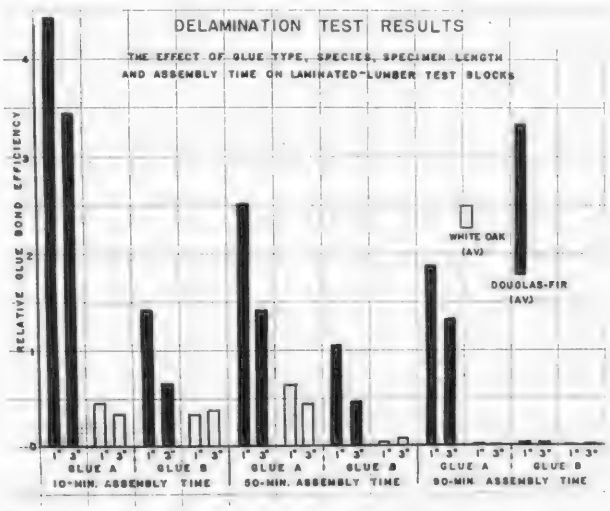

DELAMINATION TEST RESULTS
THE EFFECT OF GLUE TYPE, SPECIES, SPECIMEN LENGTH AND ASSEMBLY TIME ON LAMINATED-LUMBER TEST BLOCKS
RELATIVE GLUE BOND EFFICIENCY
WHITE OAK (AV.)
DOUGLAS-FIR (AV.)
GLUE A
GLUE B
10-MIN. ASSEMBLY TIME
50-MIN. ASSEMBLY TIME
90-MIN ASSEMBLY TIME

Fig. 5.—Delamination test results. Effect of glue type, species, specimen length, and assembly time on laminated lumber test blocks.

[4] Michel, Phillip B. 1958. Unpublished report, University of Washington College of Forestry.

cycle a specimen showed 100 per cent delamination, the glue bond efficiency is $\frac{1}{100}$ or 0.01. It was necessary to inspect the specimens frequently when a delamination test of this type was being used for experimental work, because one could not predict which specimens would completely fail early in the cycling.

Some of the most important results of the study are apparent in graphical form in Fig. 5. A statistical analysis justifies the conclusion that there is a significant difference due to glue differences, assembly time differences, and differences due to specimens of each length. But the interaction of glues and species, and of glues and assembly time, is far more interesting. It is apparent that the test was sensitive enough to pick up the differences in the rate of falling off of glue efficiency with assembly time for each of the two glues, and for each species.

The differential response of glues and species probably reflects lack of optimum moisture content and curing conditions for either or both species.

Time did not permit the establishment of a correlation between this modified delamination test and the Military Specification M1L-A-397-B for marine laminates. However the results suggest the possibility of individual laminators using such a simple, automatic technique for maintaining quality control against poor glue bonds. For such application, of course, the correlation is unnecessary. The experiment further suggests that either the laminating company or an independent testing laboratory could use this low-cost test as a basis for issuing a certificate of inspection on individual shipments of laminated beams. Consultations now in progress are directed toward realization of the latter possibility.

Discussion

M. L. Selbo (U. S. Forest Products Lab): In your delamination machine, do you control the relative humidity? We have found this to be rather important in development work on cyclic delamination tests.

Mr. Campbell: No. Drying is accomplished by forced-air circulation with ample venting. In forced-air drying systems of this type, humidity control is relatively unimportant.

R. H. Ripley (Douglas Fir Plywood Assoc.): With respect to the experiment regarding the superiority of a delamination test as compared to the standard plywood shear test for evaluation of glue-bond quality for white-pocket exterior panels, it would seem that correlation between the delamination test and actual outdoor exposure of test panels would be an important part of such an experiment. Is there information on this point?

Mr. Blanchard: Obviously in a project of this nature, time did not permit the development of a history of meaningful outdoor exposure data. However, the glues used for this work were DFPA-approved exterior or phenolic adhesives for which adequate outdoor exposure data are available.

Mr. Ripley: In discussing the relative effectiveness of the delamination test and plywood shear test using per cent wood failure as the criterion, the point was made that the per cent wood failure method was inferior to the delamination test because the former was sensitive to grain type and wood quality as well as to glue type whereas the latter was sensitive to glue type only. We would think that since the characteristics of the components in glued assemblies are critical with respect to bond quality, that such sensitivity would be desirable attribute to the test method.

Dr. Bryant: On the contrary. If the evaluation method is sensitive to such variables as species, density, and lathe-check orientation, the influence of these variables can only confound the accuracy of the glue-bond test. Our hypothesis was that an accelerated delamination test comes closer to a short-time index of long-time resistance to delamination, which, in turn, is the ultimate criterion of glue-bond performance. Let us reiterate that the validity of this hypothesis resulted from studies of non-standard plywood.

Mr. Ripley: The point was made that a delamination test for interior type glue bonds is a better method of evaluating bond quality than is the shear test method using per cent wood failure as a criterion. To my knowledge the percentage of wood failure occurring in plywood shear test specimens is not only used to evaluate interior type glue bonds in quality control work nor is it a provision in performance specifications. It is not used because it has not been correlated with normal use exposures for interior plywood, and because it has significance only when used with a given cyclic test which, in combination with per cent wood failure has been correlated with an actual use condition such as has been accomplished with the exterior test described in Commercial Standards CS45-55 and CS122-56. A delamination test is probably the proper method of evaluating interior type glue bonds provided the test cycle used is correlated with actual use conditions and provided it will detect poorly bonded plywood and glues that are not suited to the actual use conditions to which the plywood may be exposed.

Mr. Campbell: The purpose of the work to which you referred was to develop an adequate test for evaluating glue-bond quality only in those plywood constructions not now tested by CS 45–55. In the April 1958 issue of the FOREST PRODUCTS JOURNAL, there is reported a comparison of four methods for evaluating non-standard plywood constructions (softwood—hardwood combinations). To my knowledge, none of the four methods used —wood failure, accelerated delamination, shear strength, and cleavage strength—are presently being used for quality-control purposes or as a commercial standard. The accelerated delamination test most nearly approaches the standard 10-cycle interior test of all the methods studied.

Mr. Ripley: The 1-hour soak conditions and 3 hour drying cycle with 1x10 inch test specimen reported on by Mr. Campbell will undoubtedly break down a weak joint. What data are available on the effectiveness of the 1-hour soak in evaluating the *water resistance* characteristics of interior type adhesives?

Mr. Campbell: Any delamination test involving a water soak measures the relative water resistance of the adhesive bond. The effectiveness of the soaking period depends upon the specific technique employed. Thorough wetting occurs in one hour in the commercial model machine, which is based on a high-temperature drying cycle and a one-inch wide specimen.

Mr. Ripley: The point was made that a mill quality control program made possible by the use of techniques developed in conjunction with an automatic delamination machine would make it possible for a mill to certify as to the quality of its product. Where certification is necessary, specifiers in general require that certification be made by an impartial, accredited testing agency. The question naturally arises whether self-certification would be acceptable by specifiers?

Mr. Campbell: A producer that can certify the quality of his product and can, by performance, live up to his certification is in a better business position than is a producer who cannot make a certification. Repeat sales are made by confidence in the supplier and his product. It is sound business to inspect and ascertain the quality of the product being sold. If the producer is unable to meet his performance certification and a question arises over the product, or if the purchaser requests it, an impartial testing agency is usually called in.

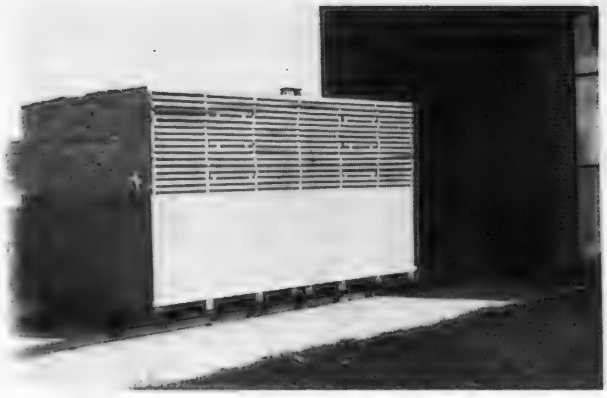


Fig. 1.—Load ready for predrying in the modified test kiln.

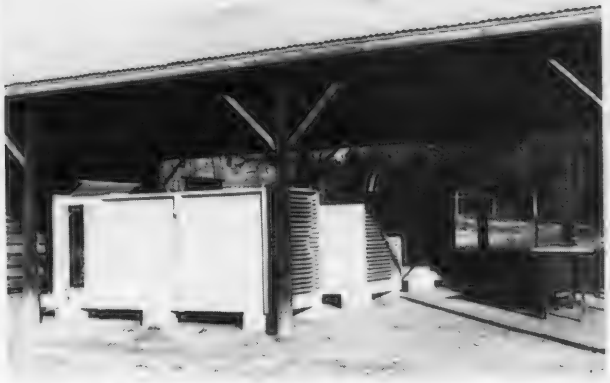


Fig. 2.—Experimental wind tunnels for predrying tests.

OPERATION PREDRY . . .

Variables in Drying Southern Pine[1]

L. I. Gaby

Southeastern Forest Experiment Station, Forest Service, U.S.D.A., Athens, Ga.

Southern yellow pine lumber was predried with highly satisfactory results. Degrade was low, and lumber could be dried to about 15% MC in 4 to 8 days.

WESTERN LUMBER PRODUCERS HAVE HAD considerable success predrying softwood lumber by various methods.[2, 3] Some report substantial savings through decreased drying time, reduced yard space needs, and increased dry kiln capacity. Others credit predrying with reduction in seasoning degrade and more uniform final moisture content throughout loads. The significant advantages of predrying western softwoods should also apply to southern pine.

The term *predrying* refers to a method of removing moisture in wood from the green condition to about 20 percent moisture content by means of constant forced air circulation with or without some heat. Predryers may take the place of or supplement conventional air drying.

Two distinct methods of predrying are in commercial use today. One uses large air-tight buildings with capacities of 20 to 400 M.b.m. These buildings have large fans, overhead vents, and heating coils for supplemental heat. The air makes one pass through the lumber in some structures; in others it is recirculated with added fresh air. The controllable drying conditions usually are unchanged during the predrying operation. The other method makes use of large mobile fans to force or pull air through lumber piles located on the yard. Some type of baffling is needed to prevent bypassing of the air. The air circulated by the mobile yard predryer is, of course, at the prevailing air temperature and humidity. The main characteristic of predrying is the use of forced air circulation.

The study reported in this paper is being conducted at Athens, Georgia, by the Southeastern Forest Experiment Station in cooperation with the Forest Products Laboratory, the School of Forestry, University of Georgia, and industrial cooperators. This is an interim report on the first of several studies intended to provide information necessary to design and operate efficient commercial lumber predryers.

Objectives

The primary objectives of the study are to determine the effect of various air velocities on the drying time and lumber degrade of 4/4 rough green southern pine lumber. Secondary objectives are to determine the effect of equilibrium moisture-content conditions on drying time, the uniformity of final moisture content, and the electric power requirements of the fans at various air velocities.

Equipment

A small commercial-size circulation dry kiln at the University of Georgia was used for most of the tests (Fig. 1). The capacity of this kiln is approximately 6 M.b.m. A common shaft powered by a 10 hp motor turns three 48-inch fans. Venting is through four roof vents, each 18 inches square. Heat is supplied by steam from the University system. In addition to the usual dry kiln controls and recorders, a watt-hour meter was installed to measure power consumption of the fan motor. Continuous recorders were also placed inside and outside the kiln to provide hourly data on temperature and relative humidity for use in calculating the changing EMC conditions. The dry kiln was used because of its convenience, and any further reference made to tests in the dry kiln refers to predrying tests only, and not to conventional dry kiln operation.

In addtion to the dry kiln, three small wind tunnels were constructed to supplement the kiln data and to provide information that could not be ob-

[1] Presented at Session XI, Wood Drying (Applied), FPRS 12th National Meeting, June 22–27, 1958, Madison, Wis.

[2] Anon. 1954. Predrying boosts production. The Lumberman. Aug. 98–104.

[3] Anon. 1955. Predriers pay, perform well. The Timberman. V. 57, No. 2.

The Author: Louis Gaby holds a BS from the University of Florida, and a MF from Duke University. He was a forester for TVA prior to 1956, and is now a technologist at the Athens–Macon Research Center of the Southeastern Station.

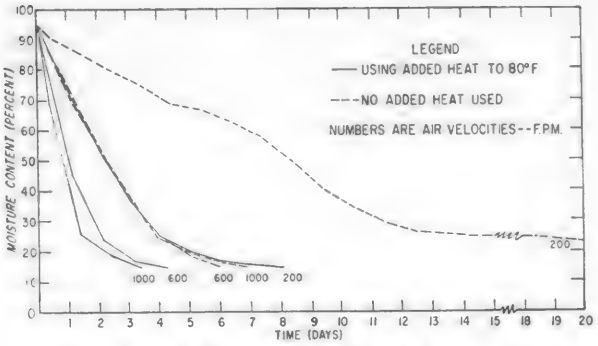


Fig. 3.—Pine lumber (4/4) predried at three air velocities in the dry kiln.

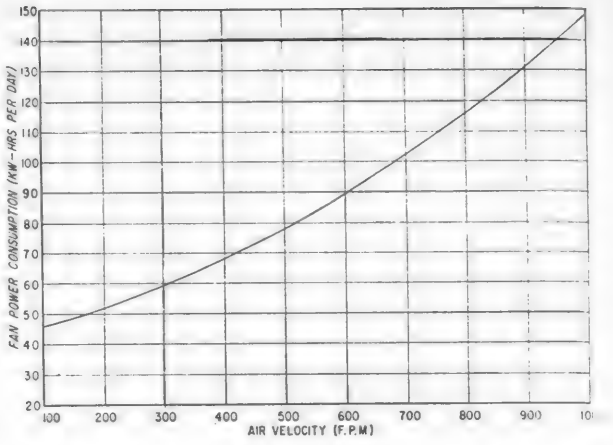


Fig. 4.—Power consumption at various air velocities in the dry kiln.

tained in the dry kiln (Fig. 2). Each tunnel is four feet square in cross section, and the length can be extended from the basic eight feet to longer lengths in multiples of eight feet. Air is pulled through the load in the tunnel by a fan 44 inches in diameter. An open shed protects the tunnels from inclement weather, but air moves freely in the test area. An instrument continuously records temperature and relative humidity during the tests.

Test Procedure

Lumber Load: In the dry kiln tests, uniform loads of 15 courses of rough green 4/4 pine lumber were piled on a platform to reduce the amount of test lumber required (Fig. 1). This platform is also an air barrier and centers the load in the middle of the drying area of the kiln chamber. Each course of lumber was 8 feet wide and 12 feet long and was made up of 14 or 15 boards. The boards were piled edge to edge on 1-inch-thick stickers spaced 2 feet apart. A layer of heavy 2-inch planks was placed on top of the load to give protection and weight to the top course. Approximately 1,300 board feet of lumber was required for each test.

In the tunnel tests, 22 courses of boards 4 feet long were piled edge to edge on 1-inch stickers to fill the tunnel. The middle six courses constituted the test area and were made up of green boards. The two center courses in the test area contained full-length sample boards. Two courses above and below the sample courses provided a buffer zone of green lumber to insure that green material surrounded the sample boards. The remainder of the tunnel load was used again for other tests. Data were obtained only from the sample boards.

Sample Boards: Six sample boards were placed in each side of the dry kiln loads to determine daily moisture content. These samples were carefully selected from the wettest material within thickness limits of 1 to 1⅛ inches. In addtion to being used for determining daily moisture content, these sample boards were used at the end of the run to check calculated moisture contents, final moisture contents, moisture gradients, and drying stresses.

Sample boards for use in the tunnel tests were selected in the same manner as those used in the kiln tests. Each tunnel contained two courses in which every other board was a sample board for a total of 14 samples per tunnel. To eliminate differences between sample boards, three 4-foot samples were cut from the same board and distributed among the three tunnels for the same position. The samples were weighed daily and retained at the end of the run for further analysis.

Air Velocities: The air velocities for the tests in the dry kiln were varied by using a different number of fans. Air velocities averaged about 1,000 feet per minute when all three fans were used. When only the two end fans were used, an average air velocity of about 600 fpm could be obtained. The center fan alone gave an average air velocity of about 200 fpm. Velocities of 1,000, 600, and 200 were the approximate average values used in the predrying tests conducted in the kiln. The actual average air velocity for each test, however, was determined by measuring the velocity in each sticker opening on the air-exit side of the load. Measurements were made with a thermoanemometer soon after the test was started in order to adjust for any large differences in velocities. During the tests, the fans were reversed every 3 hours.

Air velocities in the three tunnels were varied by changing the pulley ratios, changing the vent openings to permit air to bypass the load, or both. Velocities of 300, 500, and 800 fpm

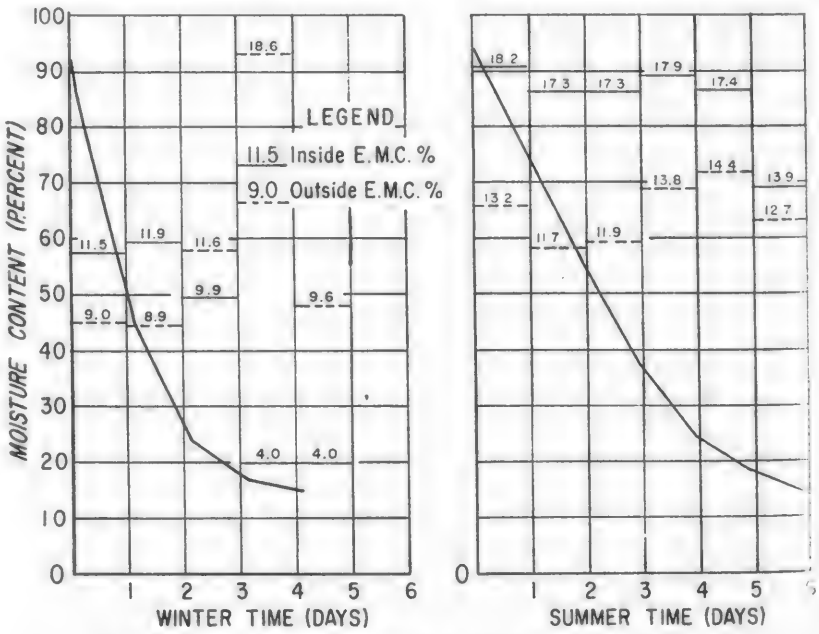


Fig. 5.—EMC conditions for two tests at 600 fpm during two seasons.

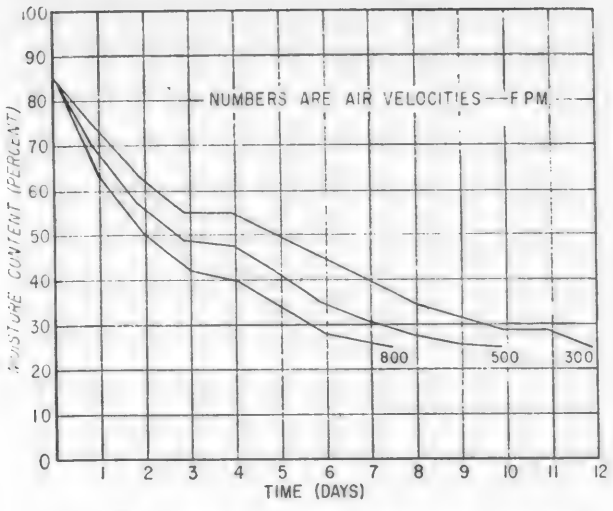


Fig. 6.—Pine lumber (4/4) predried at three air velocities simultaneously in wind tunnels during winter.

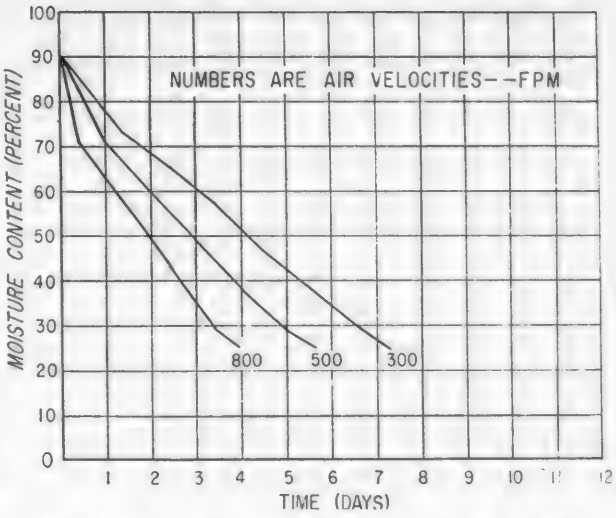


Fig. 7.—Pine lumber (4/4) predried at three air velocities simultaneously in wind tunnels during spring.

were used. Air was pulled through the loads in the tunnel tests, and forced through the loads in the kiln.

Temperature and Vent Control: The kiln temperature was held constant at 80° F. by the use of steam when necessary. Tests conducted during the fall and winter months in Athens, Georgia, required additional heat, but in the spring and summer months this was not necessary. Temperatures for these tests, with or without heat, averaged 79° to 82° F. Vents were open continuously during each run.

Seasoning Degrade: After each predrying test, every test board was graded twice as it was unloaded. The first time its grade was determined without seasoning defects. If a grade change resulted from seasoning defects, the cause of defect and a second grade were recorded. Grading was done according to the rules of the Southern Pine Inspection Bureau. Eighty-seven per cent of the boards inspected were of common grade.

Final Moisture Content: At the end of each test, the final moisture content of every board in the load was checked with an electric moisture meter. Readings were taken in the center of each board, and an average final moisture content was determined for each load.

Analysis and Results

Comparison of the drying time in the dry kiln was computed at the three velocities from an average initial moisture content of 95 per cent to an average final moisture content of 15 per cent (Fig. 3).

Tests at the lowest air velocity, approximately 200 fpm, indicated that 1/4 pine lumber could be predried from 95 per cent MC down to 15 per cent MC in 8 days at a constant temperature of 80° F. under winter conditions. However, one test conducted at this velocity but with no heat during rainy fall weather that averaged 65° F. and 79 per cent relative humidity, required 28 days. Lumber dried in the winter at 600 fpm and 80° F. dried in 4 days. The same test conducted in the summer months, without additional heat, took 6 days. Increasing air velocities from 600 fpm to 1,000 fpm did not markedly decrease drying time. At 1,000 fpm 3½ days were needed during the winter months at 80° F. This same high velocity required an additional 3 to 6 days of drying time during the summer months.

The electricity used by the dry kiln was metered for each test to give an indication of the power requirements for the three velocities used. The daily kw.–hrs. required for the velocities of 200, 600, and 1,000 fpm were: 52, 89, and 148, respectively, for these test conditions (Fig. 4). With the low-velocity consumption as a base figure, there was a 71 per cent increase in power requirements at 600 fpm and a 185 per cent increase at 1,000 fpm.

Outside equilibrium moisture conditions greatly influenced seasonal results. Additional heat was necessary during the winter months to maintain a constant 80° F. temperature in the kiln. In drying from the green condition to approximate fiber saturation, EMC conditions inside the dry kiln during the winter averaged from 3 to 4 per cent lower than during the summer (Fig. 5). Because of the varying outdoor conditions, the results of different air velocities versus drying time were not as clear-cut as desired.

In order to show clearly that drying time decreased with increased air velocities, tests were conducted simultaneously at three velocities in the three wind tunnels. The results at air velocities of 300, 550, and 800 fpm in separate tunnels under the same EMC conditions were as expected. During the winter when temperatures averaged 42° F., the drying time from 85 per cent MC to an average moisture content of 25 per cent, was 12, 10, and 7.5 days, respectively, for the air velocities of 300, 500, and 800 fpm (Fig. 6).

The following spring when temperatures averaged 72° F., the drying time from the green condition (91 per cent M.C.) to an average moisture content of 25 per cent was 7.3, 5.6, and 4.0 days, respectively, for the air velocities of 300, 500 and 800 fpm (Fig. 7).

Every board in the kiln tests was checked for final moisture content with an electric moisture meter. Each drying test was terminated when the wettest sample board reached a calculated moisture content of 18 per cent. Therefore, average moisture content of the load based on sample boards was usually 3 to 4 per cent below 18 per cent. The average of final moisture-content meter readings agreed closely with the average of sample board percentages, and, except for one load, all meter readings were under 18 per cent. In several loads tested, 50 per cent or more of the boards were dried to 12 per cent MC or below.

Conclusions

Results of this study indicate that 4/4 southern pine lumber can be predried green from the saw (about 95 per cent MC) to an average final moisture content of 15 per cent in 4 to 8 days under favorable conditions. When a low constant temperature of about 80° F. is maintained, the drying time will depend on the air velocity used

and season of year. Three air velocities, 200, 600, and 1,000, were tested and their fan power requirements metered. Of these three velocities, 600 fpm was found to be the optimum air velocity when drying time was evaluated with power requirements. The decreased drying time at 1,000 fpm was not economical when compared with power requirements. Power consumption at 1,000 fpm was almost twice as much as at 600 fpm. Drying at 200 fpm, though it required only 60 per cent of the power used at 600 fpm, took twice as long.

Weather conditions were important factors in predrying at all three velocities. When additional heat was used, drying at 80° F. during the winter was two to three times faster than drying during the summer. Without some additional heat, drying below 25 per cent MC during the winter months is probably not practical. Predrying under southern conditions without heat may also cause degrade from blue-stain during prolonged periods of high outside humidities.

When predrying is carried on at a low constant temperature such as 80° F., seasoning degrade will probably not exceed 5 per cent at any velocity.

RESEARCH NEEDED ON MAJOR

Problems in Wood Preservation[1]

IRA HATFIELD
Director of Research, Wood Treating Chemicals Co., St. Louis, Mo.

Wood preservation properly applies to the various forest products, from paper to plywood and posts. Within this tremendous scope, many specific research problems exist.

Tent poles will be subjected to considerable moisture and soil contact; these are receiving a hot-cold immersion treatment.

TO THE AVERAGE LAYMAN, WHEN one speaks of wood preservation, it conveys the idea that the wood will be made to last forever. One of our chief duties is to make the public aware of the fact that there are degrees of preservation, and that each has its place in relation to the product, its expected life, and the cost of giving the added life expectancy. Hence a definition of preservation would be in order. Wood preservation should be thought of as any treatment that will extend the useful life of the treated article beyond the service the product would give if the treatment had not been applied.

[1] Presented at the Fall Meeting of the Midwest Section, FPRS, Nov. 3–4, 1958, St. Louis, Mo.

The Author: Ira Hatfield holds an MS from Colorado Agricultural College, and did advanced work at the U. of Wisconsin. He is a past chairman of the FPRS Wood Preservation Division.

With such a definition in mind, let us consider some of the products that come from trees, observe what is being done at present to extend the useful life of these products by the application of preservatives, and then consider some of the research problems that need special attention in relation to the application or use of preservatives.

Protection of Pulpwood

One of the early forest products that is obtained from the forests is pulpwood. It matters not whether this pulpwood goes to a paper mill or a board mill, certain use of preservatives aids in getting maximum utility from such pulpwood. Whether the pulpwood is temporarily stored in the woods, at a railroad siding, or at a paper mill or other processing plant, protection of the wood against decay and insects is often a paying proposition.

Not all protective measures consist of the application of chemicals. Proper management of the storage conditions to assure as rapid turn-over of the pulpwood as possible, good housekeeping, and chemical aids may all be a part of the profitable operation. Many plants already use preservatives to protect the wet pulp. Such chemicals are usually added at or near the headbox. Where either finished paper or board-types are involved and insect- or fungus-free end products are desired, the chemical treatment may be added at one of several places in the manufacture of the product.

Certain problems have plagued those who have desired to produce preservative-treated end products. Certainly not the least of these is the volume of product that must be made before the production contains the per cent of preservative desired, and then the amount of "sub-treated" material that comes off as the contract for treated material is filled. This means that there is considerable production that contains preservative that must be given away in order to sell other material.

Furthermore, there seems to be no one treatment that will render the pa-

All poles and lumber used in this pole shed were pressure treated to assure long service life and low maintenance since wood is in direct contact with the soil.

The wood outdoor stage of the St. Louis Municipal Opera was pressure treated with water-repellent penta preservative because of the anticipated exposure conditions.

per product bacteria, fungus, and insect resistant, and still meet the requirements of the pure food laws, which call for the material not only to be relatively non-toxic to humans, but also a non-contaminant so far as food is concerned. The need for a cheap preservative that is a good biological protectant yet relatively non-toxic to man and that can be easily applied to paper products is certainly still to be found. Some progress has been made, but the field is still open.

Treated Fence Posts on the Increase

It is estimated that hundreds of millions of fence posts are set annually in the United States. That may be wonderful from the standpoint of wood utilization, but it certainly is not economical if the posts are not preservative treated and therefore will require early replacement. A great deal of extension work has been done to convince farmers, highway departments, railroads and others about the value of using wood posts, and more particularly, preservative-treated wood posts.

One of the first steps had to be to get users of wood posts to consider any treatment whatever. It was therefore normal that a great deal of attention should be and was directed toward the cold-soak method of treatment. Various organizations such as the Northeastern Wood Preservation Conference, the Tennessee Valley Authority in cooperation with the Coordinated Wood Preservation Council, as well as State Experiment Stations directed experiments and kept records on the results of cold-soak treatment of posts. These studies showed that in almost all cases, the life of the posts was measurably extended beyond the life of similar untreated posts, but nonuniformity of treatment and inadequate penetration and retention of preservative often resulted from this type of treatment.

Many pressure treating plants became aggressive in the matter of providing pressure-treated posts, and the utilization of properly treated fence posts is on the increase.

Three distinct research problems should be of interest in this area. One is to obtain more information on the treatability and utility of little-used species of wood as sources for fence posts; another is a better accumulation of service records on treated posts according to species, type of treatment, preservative used, and locality of installation; and the third is a good market research to point the way to why wood posts are preferable to many substitute materials and to show the market potential by areas and according to type and classes of posts.

Treatment of Poles in Line Needs Study

The use of wood preservatives for the treatment of poles is one of the older established uses for preservatives in the United States. Two phases of treatment have been given considerable attention—the thermal process (hot-cold treatment) and the pressure process.

In more recent times, the treatment of poles in line to increase the service of either the tops or ground line has received increased attention. The research problems in this field that need study would certainly include methods of getting adequate distribution of preservative without producing bleeders and without excessive retentions, better inspection methods, and—it must be admitted—ways of preventing woodpecker attack.

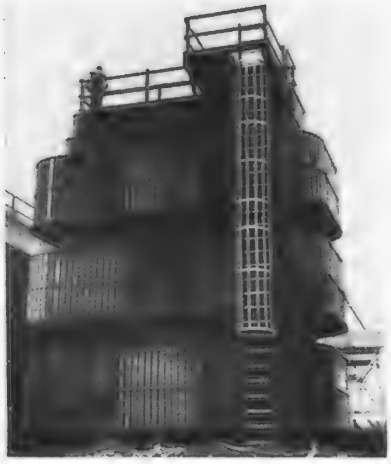
Advantages of Wood Piling

Many good papers dealing with the merits of wood piles have appeared in recent years. The comparative costs and other advantages of wood over competitive products have been featured. Because the cost of replacing piles is almost always high, a study of the possible original cost in relation to the replacement cost for given end uses and under certain service conditions would certainly help design engineers as well as procurement agencies decide on how good an original treatment could be afforded. It is well known that even the best available treatments as presently conceived leave something to be desired as far as service life is concerned under certain conditions of marine use. It is quite possible that better and more lasting treatments could be devised, but it is also quite probable they will not be available at prices presently quoted for creosote and creosote mixtures. It is difficult to get research organizations to budget money for this field of research when there appears to be so little chance for a return on the investment according to present methods of procurement. Here as well as in many other phases of wood preservation research, the tendency is to see if "by-product" information can be utilized in the field rather than to expend efforts to find direct answers to an important problem.

Crossties and Switch Ties

Although vapor drying has made some headway for the seasoning of ties, there is still need for satisfactory methods for reducing seasoning periods, a need for ways to reduce checking during seasoning and use, and a need for an economical, durable, and practical type of tie coating material.

With the trend toward putting more tonnage of freight over the tracks per day in order to reduce trackage, ties will probably tend to wear out before they rot out. It is conceivable that treatments can be devised that will make possible the production of a better initial tie, and that the same treatment will add to the mechanical life of the tie.



The life of cooling towers can be extended by preservative-treating the wood, which is subjected to a constant flow of water.

Wood Block Floors Could Be Popularized

Much still could be done to popularize wood block floors in industrial plants as well as in work areas where there is much human traffic. Better methods of handling the blocks as units in order to reduce labor costs is one method of increasing their use, and the development of suitable spacing materials that will compensate for contraction and expansion of the wood is another. With the development of some of the new wood finishes that have good abrasion resistance, it should be possible to devise satisfactory preservative treatments other than creosote that would make it possible to retain the grain pattern of the wood and extend the places where wood block floors would be desired.

Water-Repellent Preservatives for Dimension Stock

Considerable progress has been made in the development of water-repellent preservative treatments for wood to be used in areas where little or no color or odor can be tolerated in the treated wood. At the present time there is some confusion as to the relative merits of different methods of treating the wood and the properties imparted by the treatments.

Although much of the wood might be used above ground where less than the conventional retentions of preservative conceivably might furnish adequate protection, it is known that certain types of construction allow considerable condensation to occur on the wood and also make termite attack a possibility. Data are generally lacking on the preservative retentions and the distribution of the preservative in the wood that have furnished adequate protection under service conditions. With such information lacking, retentions ranging from 2 to 6 or 8 pounds of penta petroleum solution, for example, have been recommended by "dippers", vacuum treaters, or pressure treaters.

The development of suitable fire retardants to be combined with this type of treatment is also a research challenge.

Lumber is the Greatest Creative Area

Under this heading could be considered not only 4/4 and 8/4 items such as studs, joists, plates, boards, and so forth, but also the multitude of products made from them such as pallets, crates, boxes, food containers, refrigerators, and scores of other specialty items. Research-wise, this field of wood preservation furnishes one of the greatest areas to be creative, for there are so many phases of the problem that need attention that one need not feel stifled. Certainly the range goes from handling techniques to protective products to be applied to the wood, and covers such chemical types as non-poisonous or non-irritating chemicals that could be safely used next to foods and to products that would impart fire retardance and dimensional stability to the wood.

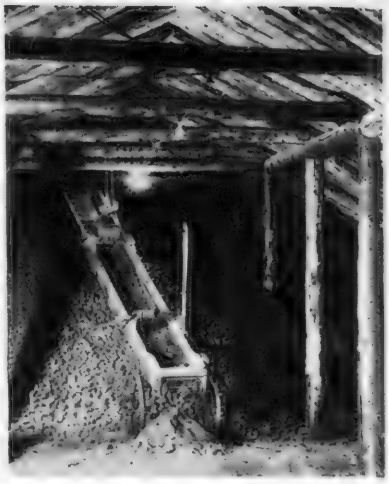
Wood finishes that will have good adherence to treated wood and that can be applied by a hot or other process to get quick handleability of the wood are also a must if wood is to be fabricated cheaply and quickly. Suitable treatments for wood siding, wood shingles, and other exterior items are receiving renewed attention, and interesting progress is already being made toward the perfection of better treatments for use on these items.

Millwork Now Enjoys a Good Competitive Position

Two outstanding papers relative to the preservative treatment of millwork make up a part of this issue of the JOURNAL. The studies made through the cooperation of the National Woodwork Manufacturers Association, the chemical companies producing wood preservatives, the U. S. Forest Products Laboratory, and the millwork producers has set a pattern that other segments of the wood products industry could well study.

A realistic approach as to why wood was losing ground in public favor, and an equally realistic approach on how to make wood millwork perform in a satisfactory manner has put wood millwork in a good competitive position against the substitute products that once plagued it.

Problems inherent with the species of wood used for the production of millwork, such as "sinker stock" and the retention of oils by the wood resins, have created headaches relative to the application of finishes to some of the wood, but these problems are not confined to the millwork industry, and the various segments of the wood industry can well afford to pool research effort and money toward finding solutions to these problems.



Pentachlorophenol assures poles and posts of long life, even in this dark potato cellar.

Little Preservative Effort Has Been Spent on Veneer and Plywood

The demand for veneer and plywood has often been sufficient so that the products were sold without much consideration being given to how to produce better types that would serve the public more satisfactorily. Although great progress has been made in finding better adhesives, better ways to cut veneer, better ways to up-grade degrade material, and so forth, one has only to look at too great a percentage of plywood to see that the wrong grade has often been used for paneling on everything from automobile bodies to garage doors. Either the grade of product or the educational program one uses needs careful attention.

Little is done to preservative-treat veneer before it is laid-up as plywood, yet the treating could be done much more cheaply then than in 4 by 8 foot panels. Little has been done to perfect ways to keep panels in doors from developing longitudinal checks that mar the beauty of natural or pigmented finishes. A discussion of quality is for the most part left to the advertising of glue or adhesive manufacturers rather than to charts and tables that could relate glue types and plywood grades to the best performance for given end uses. And again it should be said, the wood industry and the paint industry must work together more closely if metals and plastics are to be

ept from taking away future markets or both wood and paint.

Wood By-Products Need Aggressive Thinking

Although the name may be a mis-mer, much could be said about the eeded research on the subject of add-g preservatives to the wide range of ood by-product materials such as low-d high-density boards, sawdust and ip products, and the like. There are any uses for these wood products here the addition of suitable pre-rvatives according to the anticipated nd use would increase the service life d utility of the product.

It is almost certain that the best chemicals for many of these uses have not yet been developed, but enough is known about presently available products to have made their use much more widespread than practice indicates. Almost all of these cellulosic products have to go through a drying process somewhere during the manufacturing operation, and it seems logical that the treatments will therefore be most economically applied in a water solution prior to the drying operation. This area needs more aggressive research thinking.

General Research "Across the Board"

So far, the discussion has been about specific wood products. There are certain problems that could be profitably tackled by researchers in the field of forest products that cut across many of the end-uses discussed. One such problem deals with the development of better test methods to demonstrate performance. Along with that phase goes the development of better inspection methods to guarantee better performance of treated products. There are several technical papers needed to help advance both research and utilization of research knowledge on wood preservation. A periodic up-to-date listing of state and federal bulletins and circulars dealing with wood preservation would be very helpful. If the list were indexed by states, it could be readily utilized by extension agencies as well as wood purveyors or users. At present, the average person has a difficult time learning what information is available and from where.

There is no comprehensive listing of experimental wood preservation plants that gives the size and whether the owner (school, technical research group, or industry) is in a position to take on outside research or accept projects for research studies.

A table on recommended treating practices, recommended chemicals, and recommended retentions according to the end uses for the various wood products would certainly be useful to architects, engineers, and others who are interested in the proper use of treated wood.

This discussion has been an attempt to hit some of the high spots in the field of preservative problems that need research attention. If it has stimulated interest in only one or two of these areas, the efforts will have been worthwhile. Certainly the Forest Products Research Society should be the fountainhead for the stimulation of interest and scientific endeavors in this field.

PRESSURE OF COMPETING MATERIALS:

Why Some Wood Products Hold Their Own[1]

C. M. Burpee
Executive Director, American Wood Preserves Institute, Chicago, Ill.

Since the history of early man, wood has been rated one of the most economical and useful building materials. But it, too, has its natural enemies and limitations. Just as modern metallurgy has developed alloys that resist corrosion and other destructive agencies, however, so has modern research produced treated timber products designed for the construction of long-lasting structures.

TODAY'S PROPERLY PRESERVED Douglas-fir, gum, oak, southern pine, and other commercial species will long outlast Nature's so-called durable woods with their limited resistance to decay and attacks by termites and other insects. Moreover, modern treatments with fire-retardant chemicals provide today's architects, engineers, and builders with reliable construction lumber that reduces the risk of holocausts and permits the control of what otherwise might prove to be disastrous fires.

Wood so treated prevented a raging fire from destroying a Navy blimp hangar, 1,000 ft. long and 170 ft. high, at Tillamook, Oregon, in the summer of 1956. Shortly after the fire broke out, the mammoth blaze raced up the inflammable roof coating and the crowd shouted, "There she goes!" —but "she" didn't. One hour after the blaze broke out, it was brought under control and damage was restricted to less than one per cent of the $6 million replacement cost.

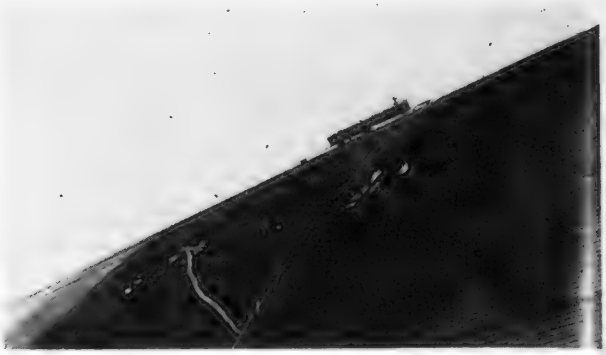
The lumber in that hangar had been impregnated by forcing an approved preservative deep into the wood, under pressure in a closed cylinder. Modern construction timber can be successfully protected against the ravages of other wood-destroying agencies by the same method and the use of time-tested and approved preservatives.

The wood products of today's treating plants were not developed overnight. Wood preservation in this country began in an humble way more than

[1] Presented at the Fall Meeting of the Mid-west Section, FPRS, Nov. 3–4, 1958, St. Louis, Mo.

The Author: C. Miles Burpee holds BS and MS degrees in civil engineering from the University of New Brunswick, Canada. He held several engineering and editorial positions with railroad organizations before joining AWPI in 1954.

This fire, aided by wind and inadequate fire-fighting equipment, appeared capable of destroying the $6 million blimp hangar.



Because the wood was treated with fire-retardant chemicals, flame spread was prevented, the fire was controlled, and repairs cost only $21,000.

a century ago. But it was not until after 1885, when the price of railway crossties had advanced so that railway managements became actively concerned about ways of reducing costs by increasing service life and foresters became alarmed about the possible exhaustion of timber supplies, that three pressure treating plants were built. Ten years later 12 were in operation.

The greater part of all the timber treated in the United States prior to 1900 consisted of about 15 million crossties. In 1898, replacements of crossties in railway tracks averaged 304 per mile per year, and the railways were installing more than 100 million ties annually. The average life of untreated ties in all tracks ranged from six to a maximum of 12 years, depending on the species used. Fifty-five years ago, only 9.5 per cent of the crossties installed in track were preservatively treated.

Crossties Now Last 38 Years

Although early treating practices prolonged tie life substantially, today's average life of 38 years has been attained through continued research and improvements within the wood-preserving industry. Average yearly renewals for the last five years dropped to 82 ties per mile of track, and more than 98 per cent of all ties installed were pressure treated.

Because of their inherent resiliency, which provides a superb cushioning effect for heavy rolling loads, their comparatively light weight, which makes for ease of handling, long life and proven economy, pressure-treated wood crossties are tops. Today's railway tracks in this country are supported by more than 976 million wood ties, practically all of which are pressure preserved. That they have attained their pre-eminence through competition is evident from the fact that, during the last 50 years, more than 2,500 patents have been issued in the USA for substitutes made of other materials. For instance, at one time more than 1,000,000 steel crossties and some 25,000 reinforced concrete ties were in service, not to mention several miles of reinforced concrete slabs to which the running rails were affixed by special fastenings. Because of defects developed under traffic and excessively high costs, all were discarded and the pressure-treated wood tie remains supreme.

Railway engineers also were leaders in extending the benefits of preservative treatment to wood piles, caps, and stringers for bridges, trestles, and wharves; to foundation piles for all types of structures; to wood fence posts; and to lumber products for freight and passenger cars. The economic advantages of wood preservation have been appraised by the Bureau of Economics of the Association of American Railroads. According to their estimates, pressure-preserved timber products save the railways $\$^3/_4$ million *a day;* or about $300 million a year.

From a small beginning some 73 years ago, wood preserving has developed into a sizable, progressive, research-minded industry dedicated to increasing the life of all lumber and timber products in service. Of today's 240 pressure treating plants, only 12 are operated by railways. In 1957, the industry treated 274.5 million cu. ft. of wood. Among those products were 31.5 million crossties, or enough to lay more than 10,000 miles of track;, almost 28 million linear ft. of piles; almost 6 million poles, or enough to build 40,000 miles of pole line; about 21 million fence posts, or enough to build 52,500 miles of fence; and 500 million f.b.m. of lumber and timber.

The public utilities were not far behind the railways in adopting the use of treated poles and timber structures for transmission lines and foundation piles for power plants. Preservative treatment has extended the average service life of poles to 35 years and more. A pole line on Staten Island, N. Y., in service for 59 years, still has 208 of the original 243 pressure-creosoted poles in place, and these are heavily loaded with telephone cables, power lines, and highway lighting brackets.

Three Lighting Poles for Cost of One

Pressure-preserved wood poles are becoming more popular for use as lighting standards, primarily because of their comparatively low cost and long life. Today's treating plants with their modern peeling machines and choice of preservatives can turn out masterpieces with attractive appearance for use in cities or along country highways. With ever-increasing demands for more and better lighting, the choice often favors wood standards because three pressure-treated wood poles can be installed for approximately the same price as one metal standard. Furthermore, they are immune to corrosion, and modern preservative treatments produce a product that does not require painting.

Although railway engineers are credited with the introduction of preservatively treated wood products, the farmers of the Midwest were quick to grasp the long-term economic advantages of pressure-treated wood fence posts. Today's popularity of pressure-impregnated fence posts has been gained through years of successful service. For instance, an inspection of several miles of woven wire fencing on pressure-creosoted posts along the right-of-way of the Missouri–Kansas–Texas recently revealed that the posts were in sound condition after more than 32 years of service. Repeated annual burnings of dead grass and other vegetable matter had very little effect,

with char of the wood posts limited to ⅛ inch.

Modern Wood Posts for Highways

Because of the relatively low cost, ng life, and strength qualifications, ressure-treated wood posts are being sed extensively for fencing highways. his is particularly true of many sec- ons of the country's Interstate Sys- m, where dependable fencing is a ime requirement for limited-access, igh-speed highways. The small end the post is pointed with a mechani- l sharpener at treating plants prior t impregnation. Several types of power rivers, including attachments for standard farm tractors, install the posts rapidly and without damage. For example, one fencing contractor on the Kansas Turnpike drove some 25,000 treated wood posts in 1,000 hours, or at the rate of 25 fence posts per hour for each tractor driver and two-man crew.

Having learned from experience the advantages of properly treated fence posts, Midwestern farmers led the way almost 20 years ago in the reintroduction of pole-type buildings for barns, storage sheds, self-feeding hay keepers, broiler and laying houses, and other low-cost farm buildings. This development was characterized by the use of pressure-preserved poles and splash boards around the bases of these buildings. Thousands of these buildings have been built with owner labor in recent years at costs of less than $1.00 per sq. ft. of enclosed floor area. Contract jobs may run from 90¢ to $1.40 per sq. ft.

Costly to build and costly to operate, vertical silos of concrete or wooden staves have given way to the horizontal type supported by poles or posts and with plank walls—all of pressure-preserved wood. Not only are these much less expensive to build, but silage can be stored at much less cost and self-feeding arrangements for cattle convert them into cattle cafeterias, which in turn makes for very substantial reductions in farm labor.

Pole-type Storage for Grain

The latest invasion of pole-type structures in the farm field is for grain storage structures. Here again because of very low first costs and long lasting qualities, pressure-preserved wood is regaining markets that had been lost to concrete and steel. Among the largest developments of this kind are 12 storage buildings in Nebraska for shelled corn, wheat, and other grains. Individual structures are 71 ft. by 300 ft. in area, and provide for grain storage ranging up to a depth of 15 ft. Total storage capacity exceeds 4,000,000 bushels, and some 2,400 pressure preserved poles were required.

Over 98 per cent of all railroad ties now being installed are pressure treated. The life expectancy of these treated ties has risen to 38 years.

This 20-year-old revolutionary development already has spread from the farms to commercial and industrial fields and in fact several pole-type homes also have been built. This design, which employs pressure-preserved round timber poles for foundation, columns and supporting frame members, has the inherent advantages of low cost, ease of erection, and adaptability to many different purposes. These structures are light. Floor loads are supported independently by the ground and not by the building frame, so that elaborate, expensive masonry foundations are not required. Preserved poles serve as columns, with their bases set to moderate depths in average soils. They support these buildings safely, even in regions where provision must be made for strong winds or deep snow. Their erection is simplified because the lapping of commercial lengths of lumber obviates the necessity for any but the simplest cuts in members of the walls or roofs. Unobstructed floor areas adapted to the use of modern materials handling equipment may be readily provided by the use of simple roof trusses for the required span.

Pole-type industrial buildings with sturdy concrete floors have been built under contract for prices ranging up to $2.50 per sq. ft. of floor space, depending on requirements.

A thorough test of the sturdiness of treated pole-frame buildings occurred in 1954, when Hurrican Hazel hit the East Coast. A comprehensive survey by the Agricultural Engineering Department, University of Maryland, of the hurricane's damage to farm buildings reported no evidence of damage to good pole construction. The most outstanding example of stability during this storm was the pole-type Baltimore Livestock Auction Market, which has an area of nearly three acres under roof. This structure withstood the hurricane's 100-mile-per-hour winds without damage, although many farm buildings of ordinary construction were demolished.

Introducing Low-Cost Airplane Hangars

Because of their ready adaptability to many and varied uses, pole-type buildings may be readily adapted to hangars, particularly for small airplanes. Although scores of these hangars have been erected throughout the country, it remained for the American Wood Preservers Institute to develop standard plans for four different sizes suited to the most popular types of small planes. With more than 5,600 airports now in the country, and with relatively few hangars for small planes now in service, it is anticipated that the new plans and designs complete with bills of material and instructions for erection will lead to an extensive market for more pressure-treated poles and lumber.

Timber Piles Are Efficient and Economical

Timber foundation piles have been used continuously since the prehistoric era to provide practical foundations for heavy structures that rest on soils that have insufficient bearing strength and are unable to support footings for any but the lightest structures. Timber piles have been driven since medieval times to support many buildings and structures in Venice and all the cities of Holland.

This pole, carrying telephone cable, power lines, and lighting brackets, is one of a remarkable 60-year-old group on Staten Island, New York City.

Untreated timber piles entirely embedded in earth and cut off below the permanent water table or those submerged in *fresh* water cannot decay or be damaged by insects, and will last permanently if their surrounding conditions remain unchanged. The real hazard is an unforeseen lowering of the ground water level, and the consequent exposure of their upper portions to decay and insect attack.

The unexpected lowering of ground water table, which exposed the heads of untreated piles to decay, has necessitated costly underpinning in many instances. A costly foundation job of this kind occurred in Boston, where the Public Library, supported by untreated timber piles cut off supposedly below ground water level, had stood for many years. Subsequent construction of deep drainages nearby lowered the water table to a point well below the tops of the piles. Decay set in and the foundations had to be rebuilt to prevent failure. Similar instances have been reported in New York City, San Francisco, Milwaukee, and other cities.

Water tables throughout the country are being lowered continually because of the increasing use of water for industrial and family use. For instance, recent studies by the U. S. Geological Survey reveal that, at South St. Paul, ground water levels are from 50 ft. to 100 ft. lower than they were 25 years ago, when they were near the surface. In New Orleans, permanent ground water level is now some 17 ft. below the surface of the ground. Similar reports are available for many parts of the country. Because of the drastic lowering of ground water levels, foundation engineers are advised to consult those reports carefully. If surveys and reports are not available, the safe course should be taken—pressure-treated piles should be used to avoid running serious risks.

68-Year Service Records

Pressure-treated timber piles have been used longer than any other type of so-called permanent piling for foundations where the tops of the piles, although cut off below the ground level, extend well above the permanent water table. Their first use dates back about 68 years.

Inspections of foundations with piles driven in the ground, cut off above ground water level and encased in masonry, are rare except in instances where additions or changes are made to existing structures. An exceptional instance occurred in 1931 on the Illinois Central Railroad, where pressure-creosoted piles have been used for foundations for 60 years. Because these piles have proven so economical and so practical for so many of their structures, engineering officers decided upon a field inspection to determine their condition after many years of service. The published results of that inspection declared that in no instance was there the slightest indication of change in the preservative condition of the treated wood since the time of installation.

The proposed extension of the deck structure on a long intercity viaduct at Kansas City, Mo., in 1936 led to a careful examination of creosoted foundation piles that had been driven under 276 pedestals of the pier footings 31 years before and cut off 5 ft. or more above the water table. All were reported in good condition with no evidence of deterioration. Consequently, the use of the original footings was approved by the engineers for the revamping project.

Fifty-four years ago, in 1905, the Atchison, Topeka & Santa Fe Railway built the first unit of a large grain elevator near Kansas City on 2,078 creosoted timber piles. Although the piles were cut off beneath the surface of the ground, they ranged to as much as 20 ft. above the fluctuating ground water level. Additions were built in 1913, 1915, 1925, and 1931. It is significant that pressure-creosoted timber piles were used on each occasion until a total of 23,142 were driven to support the structure, which has a capacity of 10½ million bushels of grain.

Greater Loads Are Warranted

Pile foundations are driven where underlying soils have insufficient bearing strength to carry the superimposed

This entire 230 kv H-frame line is constructed with round material from poles regularly carried in stock. Main poles are Class 2 (70 to 95 ft), spars are Class 1 (40 ft).

loads satisfactorily on spread footings. In some cases, the piles transfer the load to some deep, stronger load-bearing stratum; in other instances the piles merely distribute their burden through considerable depths of surrounding earth by friction, thereby spreading their load sufficiently to preclude excessive concentrations on some substratum. The ability of the soil to support the load transmitted to it by the piles is the factor that determines the adequacy of the foundation, because piles cannot increase the carrying capacity of the underlying earth.

Failure to recognize this simple fact in many cases has resulted in the approval of greater loads for concrete piles than for those of wood. That there can be no logical justification for such inequalities in capacity at the same site when the piles are of equal size and are driven to the same resistance by equivalent hammer energies is evident when it is remembered that the permissible unit compressive stress for wood exceeds that of the concrete, particularly for the quality of concrete usually obtained in cast-in-place concrete piles.

That timber piles of the same size can carry the same load as piles of other materials when driven to the same resistance in the same soils, by equivalent hammer energies, has been proven on many occasions. Among notable experiments in this connection were those of the Whang-poo Conservancy Board, Shanghai, China, and investigations by the U. S. Bureau of Reclamation at Ashton Dam in Nebraska in 1950.

Design loads of 25 and 30 tons for timber piles are common, and loads of 40 tons have been specified in many instances where soil conditions were

Some of the 22,000 creosoted Southern yellow pine piles being driven to support the new-building complex at New York's Idlewild Airport.

International Hotel, part of the Terminal City being built on the piles at Idlewild by the Port of New York Authority.

rant. Among the important structures in this category is the Julien Dubuque Bridge across the Mississippi River at Dubuque, Iowa, where long timber piles were driven to support some of the river piers. In fact, piles at this location were test loaded to 80 tons.

Bridges across the Seine at Paris and the Thames at London have timber piles that were designed for loads ranging from 60 to 100 tons.

To anyone familiar with Chicago's old Post Office, it is a well-known fact that the timber piles in its foundations have for more than 50 years safely and adequately carried their loads without settlement. The design load of 30 tons per pile for this structure was based on precedent established by practice of the best engineers of Europe and the United States; a practice that has been applied to thousands of important structures throughout the world. Hence, it is evident that present engineering practice, which prescribes much lower permissible loads for wood piles of standard size and quality than for other types of piles, is without basis of fact and is not warranted by any recent developments. To the contrary, there is every reason to believe that, with better methods now used in the selection and driving of timber piles, still greater dependence can be placed on their service.

The Economy of Good Design

The important economic aspects of the evaluation of soil investigations and loading tests were demonstrated recently at the Freeport, Texas, plants of The Dow Chemical Co. During the loading test, one pressure-treated timber pile was loaded to 96 tons before it failed under sustained loads. When the load on the second pile had reached 80 tons, it was necessary to stop the test because of the failure of one of the anchor shafts. The total settlement of the pile under the load of 80 tons was 0.75 in. As a result of these tests, Dow engineers decided on a design load of 40 tons per pile. As a result, the total number of piles in the new foundation was reduced to one-third the number that previously had been thought necessary by reason of design loads that were restricted to a range of 12½ to 15 tons. The maximum settlement predicted under full design load is 0.25 in. Southern pine piles 35 ft. long and pressure-treated with pentachlorophenol were driven for the foundations of the plant addition.

The recent expansion program for New York City's International Airport serves to illustrate the economic advantages of pressure-treated timber piles and investigating soil conditions at construction sites. During the preliminary stages of constructing the International Arrivals Building and two adjacent Airline Wing Buildings, soil investigations indicated that timber piles would be acceptable. The lowest of 10 bids for those foundations was based on 6,400 creosoted timber piles, and was $245,538 less than the lowest of four bids for concrete-filled steel shells. As Idlewild's new development progressed, more than 23,000 creosoted timber foundation piles were driven at a saving of more than $900,000 to the Port Authority of the City of New York.

Money-Saving Advantages of Pressure Treatment

The several wood products considered here—crossties, fence posts, poles and piles—comprise the great bulk of material processed by the wood-preserving industry. All have been faced with formidable competition by products made of competitive materials manufactured for similar purposes. By reason of modern pressure-preservative treatment with approved preservatives, these wood products are "holding their own" because of their superior service characteristics and low cost.

Most of these products are bought by large, heavy-construction customers. These include the railways, public utilities, highways, and all branches of the military services. These large users are responsible for the building and upkeep of their structures. They have learned by many years of first-hand experience the advantages of long life and the sharp reductions in upkeep and replacement costs that can be attained through the use of pressure-preserved wood products.

Like the large users who have developed their firm convictions through the years by the use of carefully maintained cost and service records, the nation's farmers have discovered for themselves the money-saving advantages of preserved wood.

Today, wood preservers, like other lumbermen, are at the marketing crossroads. In their search for new markets they are approaching the light construction field, which offers many alluring possibilities. In broadening its sights, the industry is launching an educational campaign designed to acquaint smaller lumber users, particularly future home owners, with the benefits of long-range protection and money-saving advantages of pressure-preserved structural lumber in and around their own homes. When properly promoted and sold to America's future home owners as the most positive insurance and proven protection against decay and termites, preservative treatment will be the greatest factor in regaining and retaining the home-building market for lumber.

WATER-REPELLENT TREATMENT FOR

Lumber for Military Use[1]

W. BRADLEY
Chief, Lumber Control Division, U.S. Army Engineer District, St. Louis, Mo.

The Engineer Lumber Control Office may buy 3 million bf of water-repellent lumber annually. Exact, up-to-date specifications are a must. Five areas for specification improvement are suggested.

Military requirements often call for water-repellent lumber, such as for this storage operation at the Army's Granite City Engineer Depot.

THE NEED FOR COORDINATED procurement of lumber and allied products during World War II was recognized by all services within the Department of Defense. As a result, a single procuring agency was established on a coordinated basis.

After World War II, the demand for lumber and allied products remained substantially high, and the resultant problems of procurement were realized. As a result, the Corps of Engineers was given the single service responsibility for purchasing all direct requirements of lumber and allied products for the Department of Defense. In 1950, the Chief of Engineers designated the St. Louis District as the Engineer Lumber Control Office responsible for controlling the purchasing activities of the three regional lumber purchasing offices located in St. Louis, Missouri; Atlanta, Georgia; and Portland, Oregon.

It is the responsibility of the Engineer Lumber Control Office to receive all requirements from the various Department of Defense agencies, and make the proper assignments to the regional lumber purchasing offices. When a requisition is received in the control office, it is screened in detail to insure that it is a logical, purchasable document; then it is referred to one of the regional lumber purchasing offices. Specifications on requisitions are checked closely to insure that they represent the latest in industry developments. This is particularly important in the wood preservation industry, where changes do frequently occur as a result of research and development activities. After assignment, the regional lumber purchasing offices make the purchase and subsequent delivery of the materials.

[1] Presented at the Fall Meeting of the Midwest Section, Nov. 3–4, 1958, St. Louis, Mo.

The Author: Wayne Bradley has spent 17 years with the Corps of Engineers, 12 in procurement. During a period of World War II, he was responsible for the purchase of all Quartermaster supplies for 7th Army Headquarters.

Military Lumber Requirements

For the past five years, the total procurement of lumber through the Engineer Lumber Control Office has approximated 400 million board feet annually. Last year the procurement of water-repellent preservative treated lumber amounted to a little over 1 million board feet. In past years, the volume of water-repellent lumber has amounted to 3 million board feet per year. As a buyer, the Engineer Lumber Control Office procures according to the requirements of the users within the Department of Defense. The decision as to whether lumber should be treated, and how, is made by the using agency. The users do come to the Control Office for recommendations in connection with their requirements and specifications. In addition, the Control Office is in a position to make recommendations to the using agency upon receipt of their requisitions.

Specifications

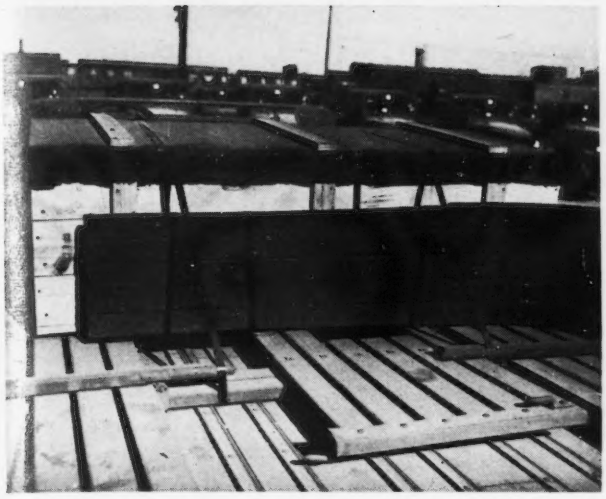
It is necessary, of course, to have clear, concise specifications. Initially, detailed specifications are necessary to permit competitive bidding. The specification constitutes the basis for bidding, and the evaluation of bids for award of contracts. For this reason, the Lumber Control Office cannot always use standards developed by industry, which are often broad in scope and not sufficiently detailed for procurement through competitive bidding. The Office prefers to use industry standards; however, because it has found that the closer it stays to commercial practice, the better price it gets because bidders can readily understand what is needed—producers are familiar with the product required.

After the award of contract, specifications enter into the procurement phase of inspection. Maintaining specifications on a current basis is a continuing job.

Customers are provided with guidelines on preparing their requirements. The Engineer Lumber Control Office, in cooperation with the U. S. Forest Products Laboratory, industry, and others, developed a Lumber and Allied Products Handbook (DSMA H-7) for use by requisitioning and using elements within the Department of Defense. This Handbook, in addition to many other items, contains a section on Wood Preservation. The Handbook is constantly undergoing revisions as new processes, methods, and materials are developed. In this way, users and requisitioners are kept informed of current industry practices. Comments and recommendations on this Handbook are always appreciated.

Specifications: Water-Repellent Preservation

Here is an example of how a specification is developed from a "need



Some of the treated wood items used for framing and racks on military vehicles.

Military packaging and pallets in many cases require water-repellent lumber.

item" to a purchasable description. For some time, a requirement existed within the military establishment for a type of preservative treatment that would meet the end-use requirements as to serviceability and still permit such material to be painted. The initial requirement was for use in the Caribbean area. To meet this military requirement, the Engineer Lumber Control Office contacted industry, explained the requirement, and with the assistance of industry, developed the existing specification. While this specification is considered a progressive step in the field of preservative treatment, improvements are always in order. Some improvements that are felt to be worthy of consideration are:

1) Under the present specification, there is only a complex method of determining retention or penetration.

2) There is no simple method of determining whether the treated lumber is, in fact, water-repellent. Should a method be devised of determining the repellency obtained? Should this repellency be specified?

3) The method of determining whether the product is paintable is not considered the best that could be devised. Can a quicker and more efficient method be developed?

4) Can inspection techniques be developed that would cover all the foregoing, that is, retention, penetration, water repellency, and paintability, to increase the assurance of the product in service, reduce inspection costs, and allow earlier shipment from the treating plant?

5) The present method of inspection at the treating plant involves inspection of the bright stock, the preservative, the treating process, and paint tests. This precludes acceptance of treated stock that may have been in inventory prior to award of contract. Can and should some technique be developed that would allow inspection of stock that had already been treated?

These are under consideration by several organizations, including an AWPA subcommittee and the Forest Products Laboratory. It is understood that research is being accomplished at the present time in these particular fields, although the final results have not yet been determined. It is hoped that the final report will ease the procurement, improve the product, increase bidding participation, and stimulate over-all adoption of an industry standard.

Whenever army engineers erect a bridge, either semi-permanent or in training exercises, a lot of wood is used.

Treatment for Storage

Studies have been made for the ELCO by the Timber Engineering Company in connection with storage. The study is about complete, and the results are very pleasing. It has been determined that lumber can be economically treated by the dip method and preserved in storage. Further work is needed to determine whether additives to certain preservatives will control stain in storage.

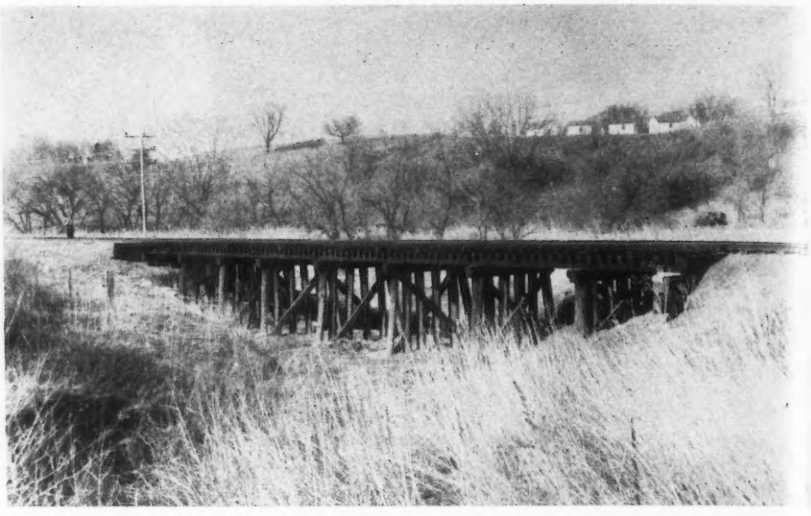
The data revealed by the study have been reduced to a chart and distributed to all interested elements of the Department of Defense. By using the chart, military users can determine what action is necessary to retain particular types of lumber in storage for any given period under various climatic conditions. These data will be especially valuable in the event of mobilization, where inventories will, of necessity, be substantially increased with possibilities of long-term storage. It is not intended that these dip-treating methods for storage supplement in any way the need for pressure-treated lumber.

PRESSURE TREATMENT CAN EXTEND

Uses for Native Hardwoods[1]

D. A. KULP
Vice-President, Casswood Industries, Beardstown, Ill.

"Native hardwood" often implies poor lumber. This need not be true. By pressure treating, Casswood makes bridge decking from bottomland American elm, outdoor furniture from cottonwood.



Making pressure-treated bridge decking and runners is one profitable answer to a local-hardwood utilization problem. *Photo courtesy AWPI.*

GENERALLY, THE TERM "NATIVE HARDWOOD" carries with it the connotation of mis-manufactured lumber marketed in the green condition by a segment of the sawmilling industry referred to, even by its own members, as the "peckerwood" sawmill operator.

Essentially, Casswood Industries is not in this category. It is a combination of a modern circular sawmill with an annual production of approximately 2½ million board feet, and a small commercial pressure-treating plant. The use of pressure-treated American elm and cottonwood represent additional products for two of the "big three' species that comprise the bottomland timber species group. Only the extremely heavy present demand for soft maple lumber has prevented further investigation into additional uses for it.

Elm Has Come Into Its Own for Bridge Decking

American elm is the bottomland species that has had the most success, primarily in its manufacture into bridge decking and subsequent pressure treatment with pentachlorophenol.

The development of this product is quite interesting. In the Spring of 1951, the majority of county bridge commissioners requested and were supplied with untreated white and bur oak bridge decking and runners. Then, upon the installation of the Casswood pressure-treating plant late in the same year, the demand changed to pressure-treated red and black oak bridge decking and runners. But there was a continual shortage of the 14- and 16-foot lumber lengths, which were in constant demand and short supply. Further, the quality of the red and black oak was rapidly declining because the "hill timber" tracts of oak had been pretty well cut over by predecessors.

About this time, the timber operations shifted from the hills and became established in the river-bottom areas of the Illinois and Sangamon.

During the manufacture of hardwood grade lumber from the river-bottom elm, it was soon evident that it did not have nearly so great a tendency to warp as did the elm grown on the upland timber sites. In this respect, it seemed as though it were a different species of wood altogether. As an experiment, a quantity of elm was manufactured and air-dried for possible use as bridge decking. Certainly, elm has many characteristics that make it suitable for this purpose, the most important of which is its resiliency or high shock resistance. Further, it is only moderately heavy and does not split too easily when nailed.

The final part of the experiment was to determine its treatability. Here it was a pleasant surprise to find that it could be pressure treated about like southern yellow pine. Therefore, without too much difficulty, the idea of penta pressure-treated elm was sold to the county bridge commissioners. They were and are satisfied in all respects with the product, and today their standing procedure is to use pressure-treated elm bridge decking and pressure-treated red and black oak runners. The elm is sawed 2½ inches thick and the widths are 8 inches and wider. Lengths generally are either 14 or 16 feet. The oak runners are 2 by 10 inches and random length. Generally they are placed side by side to provide 30 inches for each tire tread.

Treated Cottonwood Would Have an Outdoor-Furniture Market

The second bottomland timber species that has received considerable attention is cottonwood. Several years ago, Casswood manufactured a Kiddie Picnic Table from air-dried cottonwood. The design of this 40-inch table, which easily supported its 200-pound designer-foreman yet lent itself nicely to a knocked-down, shippable package, seated 4 to 6 children. This item was strictly a "market tester".

Acceptance was very favorable, even though it was realized that the "light" penta solution was not really light enough for a seating-type product (this experiment was conducted before the days when a water-repellent solution was commercially available). A picnic table such as this manufactured from kiln-dried cottonwood lumber and pressure-treated with a 5 per cent penta water-repellent solution will be a natural "natural".

[1] Presented at the Fall Meeting of the Midwest Section, FPRS, Nov. 3–4, 1958, St. Louis, Mo.

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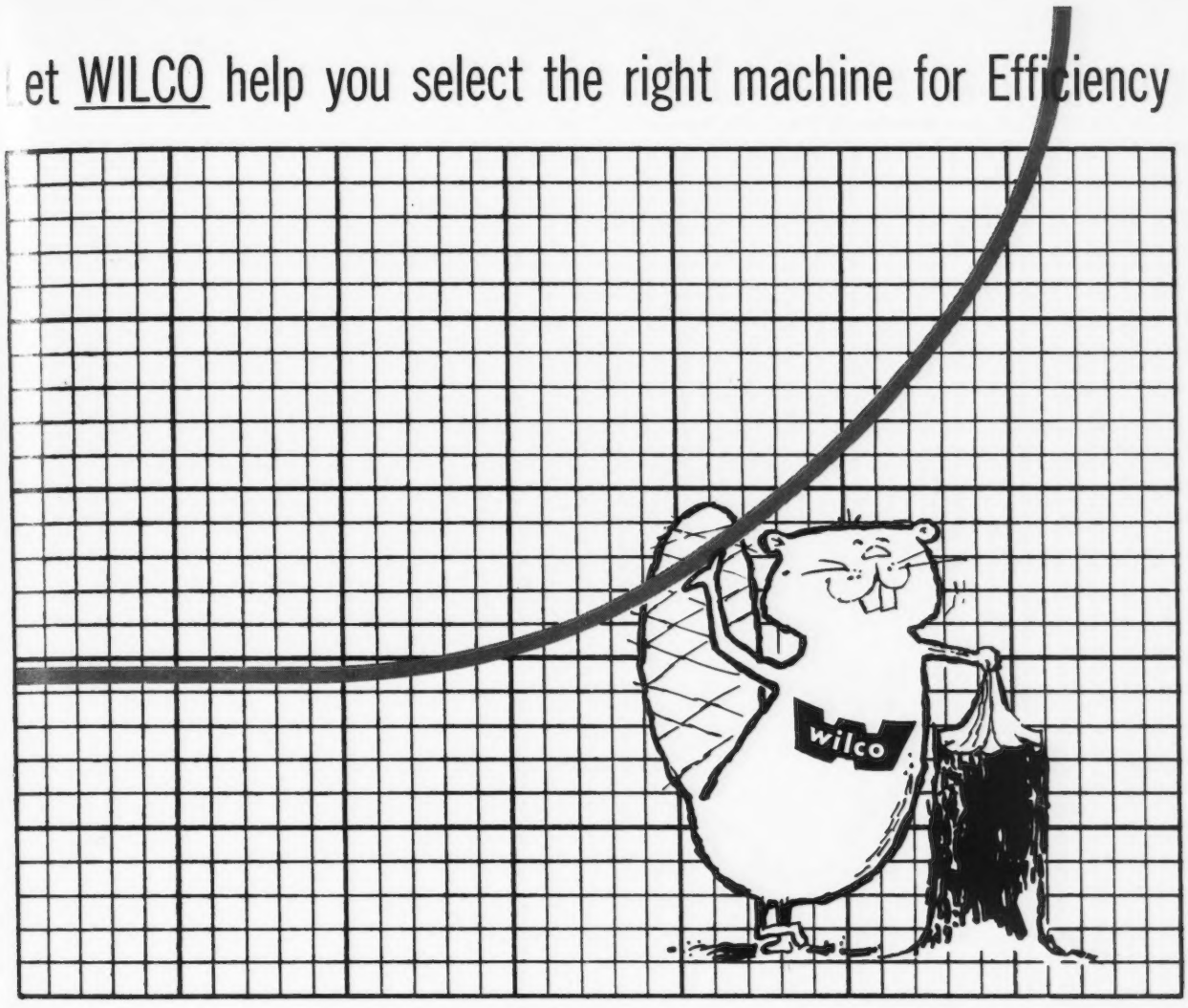

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